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# Influence of Two-Level Anchoring on the Geomechanical State of the Mass Around Mining

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***Abstract.*** *Considers the features of the application of anchor fastening of mine workings in the mines of the Karaganda coal basin. Also contains the schemes for the use of two-level fastening of the roof of the workings with changing parameters of the lateral enclosing rocks. Calculations are also given for different depth of laying, depending on the depth of laying of the workings from the surface. The presents a developed method of fastening roof rocks with an anchor bridge for their use at deep horizons (more than 600 m) with unstable direct roof and lateral enclosing rocks. As an example of the application of this solution presented the passport of fixing the roof of the conveyor drift 61k$_{12}$-з in the zone of reference pressure from the lava of the Saranskaya mine (Karaganda coal basin) using this technology.*

***Keywords:*** *anchoring, mining, stress-strain state, rocks, technological schemes, mining and geological conditions, burial depth, fastening scheme.*

**Introduction**

The current trend in the use of purposeless mining technology requires the search for reliable means of protecting the development workings, primarily adjacent to the treatment area.

Manifestations of technological factors are determined by the depth of development, the direction and speed of advancement of the preparatory faces, the methods of carrying out and protecting, the types of lining and the technological scheme of securing mine workings [1,2].

**Research materials and methods**

Analyzing the practice of using excavation workings, the main mining and geological factors influencing the conditions for their implementation and maintenance should include; the depth of occurrence, which determines the magnitude of the vertical and horizontal components of the rock pressure; thickness and dip angle; properties of host rocks.

The volume of introduction of anchoring of mine workings in the mines of the Karaganda coal basin is 12% in pure form, and 42% in mixed form. For a wider use of anchoring, it is necessary to justify its parameters depending on the development conditions, determine the area of possible and effective operation and create progressive technological schemes for its construction [2].

The main reasons for the limited scope of the use of anchoring of workings are [3]:

- complication of mining and geological and mining technical conditions with the transition to a development depth of more than 600 m;
- 35-40% increase in the cross-sectional area of the workings, especially the technological schemes of the adjacent excavation workings;
- insufficient knowledge of the geomechanical processes in the rocks around the workings at the lower horizons and the performance of the roof bolting under these conditions.

When the roof rocks are fastened, the workings in it can contain layers of near-contour rocks of different physical-mechanical, strength and geometrical parameters.

In this case, stratification and crack formation zones can be located at different distances from the excavation contour [4].

In the zone of influence of cleaning works, various fastening schemes can be applied depending on the characteristics of the roof rocks: one-, two-level and combined fastening scheme.

Figure 1 shows a diagram of a two-level support for the roof of a mine with varying parameters of the side enclosing rocks.

The predicted depth of squeezing of rocks subjected to compression across layers is in accordance with the given design scheme from the expression:

$$C = \left(\frac{k_{rt}\gamma HB}{100\sigma_c}\cos\frac{\alpha}{2} - 1\right) h\,\mathrm{tg}\frac{90^\circ - \varphi}{2}$$

where $C$ is the depth of extraction of coal or rocks in seam or rock workings, m; $K_{str}$ – the coefficient of concentration of compressive stresses in the heels of the arch of natural equilibrium, associated with the production; the choice of $K_{str}$ is made depending on the method of carrying out, the shape and ratio of the transverse dimensions of the mine; to obtain the depth of the extraction of rocks at the junctions of the workings, the values of $K_{str}$ increase by 1.4 times; $\gamma$ is the average density of rocks overlying the excavation to the surface, t/m$^3$; $H$ is the depth of the excavation from the surface, m; $B$ is the coefficient of the influence of treatment works for seam and rock excavations constructed outside the zone of influence of treatment works [5,6]; $\alpha$ is the angle of incidence of rocks, degree; $\sigma_c$ is the average strength of a compressible stratum of rocks with a thickness of h, undercut by a working, MPa; in the presence of a layer of rocks, weaker in terms of bearing capacity, in the compressed stratum, its ultimate compressive strength is taken in the calculations; $h$ is the thickness of the compressible strata of the rock layers undercut by the working, m.

In the presence of heterogeneous rocks of different strength in the undercut massif, the thickness of the layer (layers) should be understood as the thickness of the weakest member of rocks contained within $h$; $\sigma$ is the apparent angle of internal friction of rocks undercut by mining, degree. With a significant difference in the strength properties of rocks undercut by a working, the values of $\sigma$ are selected for the weakest pack of rocks within $h$ [7]. The dependence of the apparent angle of internal friction of rocks on their compressive strength is expressed by the equation:

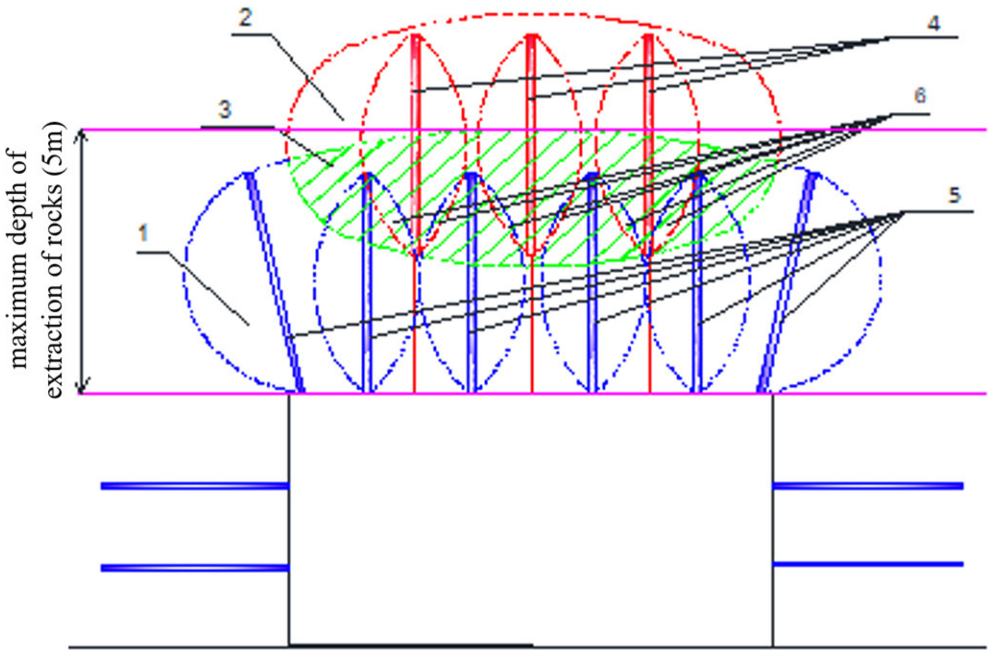
$$\sigma = \mathrm{arctg}\frac{\sigma_c}{10},$$

$$\sigma = \mathrm{arctg}\frac{24}{10} = \mathrm{arctg}2,4 = 67.$$

The choice of $K_{str}$ – the coefficient of concentration of compressive stresses in the heels of the vault of natural equilibrium associated with the excavation is made ($K_{str}$=1.5) depending on the method of conduction, the shape and ratio of the transverse dimensions of the excavation. To obtain the depth of the extraction of rocks at the junctions of the workings, the value of $K_{str}$ increases by 2-3 times (respectively, 1.5*2=3 and 1.5*3=4.5).

Depending on the depth of the excavation from the surface. The calculations show the calculations for different depths ($H$=600, 700 and 800 m).

Depending on the average strength of the compressible rock stratum ($\sigma_c$), MPa, which is taken as 10, 15 and 24 MPa.




1 – zone 1 (zone of strengthening of the roof with steel-polymer anchors); 2 – zone 2 (zone of strengthening the roof with rope anchors); 3 – zone of strengthening of the connection of zone 1 (zone of strengthening of the roof with steel-polymer anchors) and zone 2 (zone of strengthening of the roof with rope anchors); 4 – rope anchors; 5 – steel-polymer anchors; 6 – zone of maximum hardening of the connection between zone 1 and zone 2

Figure 1 – Scheme of a two-level fastening of adjoining rocks of the roof of the mine

The depth of squeezing is found at an average rock strength of 24 MPa, at a depth of 600, 700 and 800 m, it is, respectively, 0.05-1.2, 0.09-1.5 and 0.19-1.8 m.

The squeezing depth is found at an average rock strength of 15 MPa. With a depth of 600, 700 and 800 m, it is 0.35-2.28, 0.5-1.64 and 0.67-3.25 m, respectively.

The squeezing depth is found at an average rock strength of 10 MPa. With a depth of 600, 700 and 800 m, it is 0.83-3.7, 1.08-4.4 and 1.32-5.1 m, respectively.

The calculated data show that with an increase in the concentration coefficient of compressive stresses ($K_{str}$) and a decrease in the average strength of a compressible stratum ($p$), the depth of squeezing of rocks $C$, m, increases (Figure 2).

With the maximum concentration coefficient ($K_{str}=4.5$) and the minimum rock strength ($\sigma_c=10$ MPa), the squeezing depth reaches the highest level of 5.1 m.

The depth of the excavation also plays an important role, since with its growth, the depth of squeezing of rocks also increases (see Figure 2).

**Main results**

Below is a developed method of anchoring roof rocks with an anchor bridge for use in deep horizons of coal mines (more than 600 m) with an unstable immediate roof and side enclosing rocks.

The task of the technical solution is to increase the stability of the immediate roof on unstable sections of mine workings, increase the safety of work on deep horizons by stitching unstable rocks of the immediate roof and then fixing the created artificial «bridge» to the strong rocks of the main roof [8,9].

The technical result provides an improvement in the technical condition of the roof bolting, the creation of conditions for maintaining a constant section of the mine, ensuring the greatest stability of the immediate roof, reducing rock falls and increasing the service life of the roof support and is achieved due to the fact that the sewn artificially direct roof acquires an additional margin of safety in the bearing pressure zone and the rock mass created in this way is fixed with the help of deep rope anchors to the harder rocks of the main roof, represented by stable hard rocks, such as mudstone or sandstone, thereby creating the effect of strengthening the development contours and reducing rock pressure on the support – Figure 4.

This connection is carried out by installing 3 levels of anchors: an anchor of the 1st level (shallow ones – they fasten the immediate roof), deep anchors of the 2nd level (they create a connection between the anchors of the 1st level of the immediate roof and the main roof) and a deep anchor, which are rope anchors with a length of at least 5-7 m. For fastening the first level, steel-polymer anchors with a length of 2.4 m are used, and for fastening the second level, steel-polymer anchors with a length of 3.5 m (composite anchors) are used.

Three zones are created around the working: the bearing pressure zone, the elastic deformation zone and the plastic deformation zone surrounding the working. Anchoring the working begins with the face flap, namely the roof and sides of the working. The first level roof anchors are then installed with full infill. After that, the secondary level roof anchors and the side anchors are also installed with full filling. Next, deep wire rope anchors are installed with incomplete filling of the borehole. All anchors are fixed in the borehole with the mortar obtained when the anchor breaks the capsules, which are introduced into the borehole in advance. The number of holes in each hole is determined by the bottom hole fastening certificate.

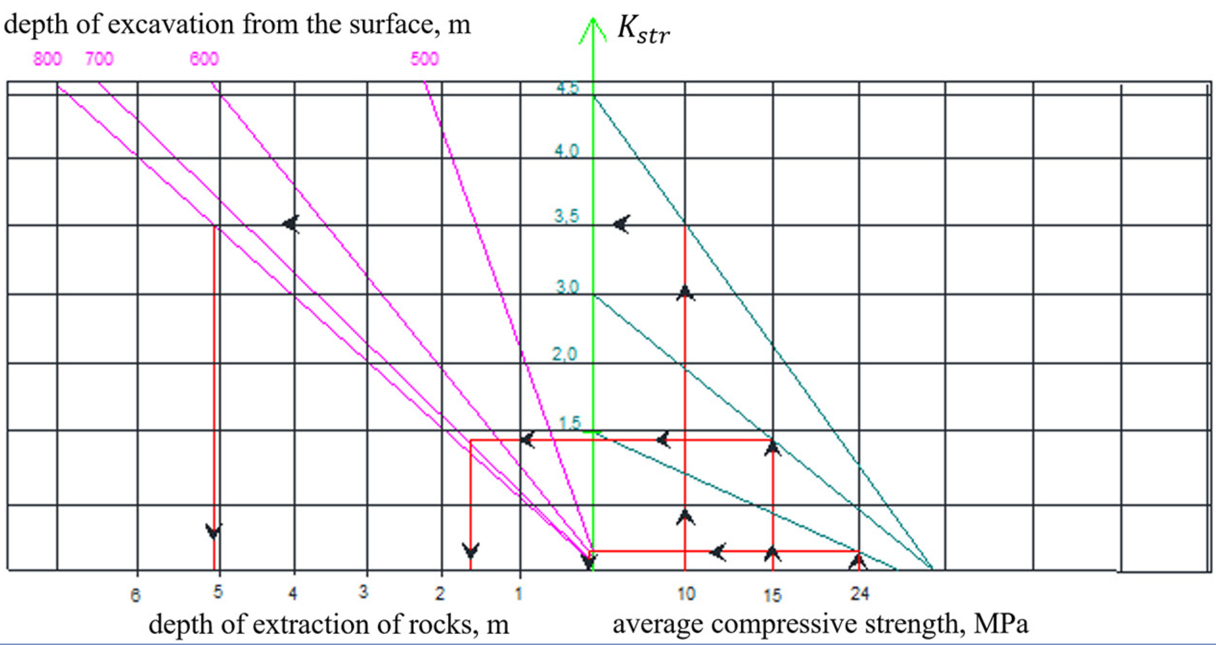



Figure 2 – Nomogram for determining the depth of extraction of rocks

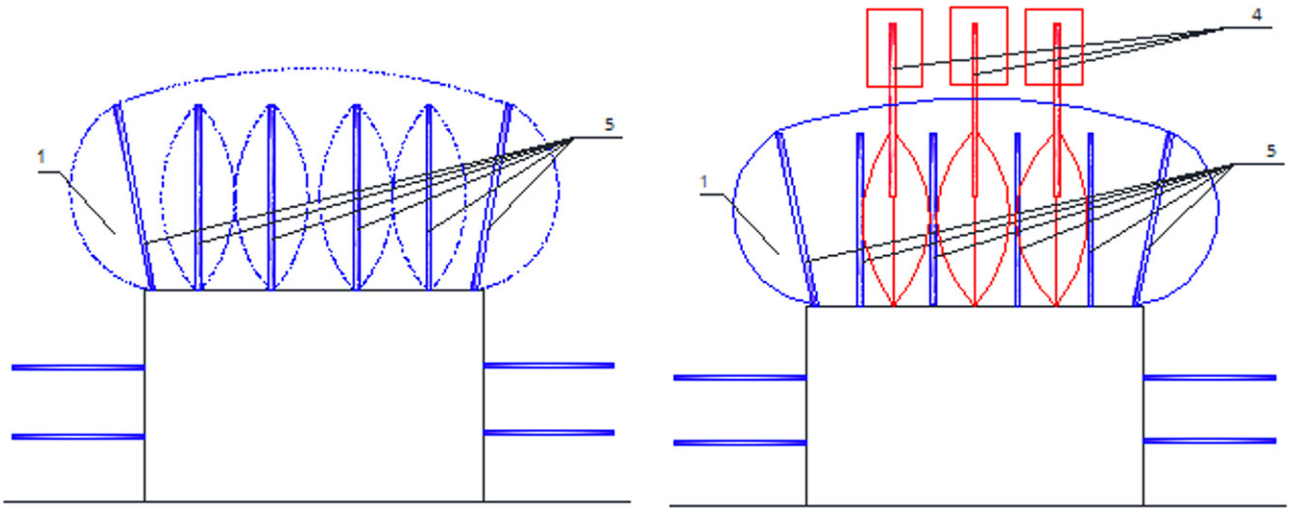
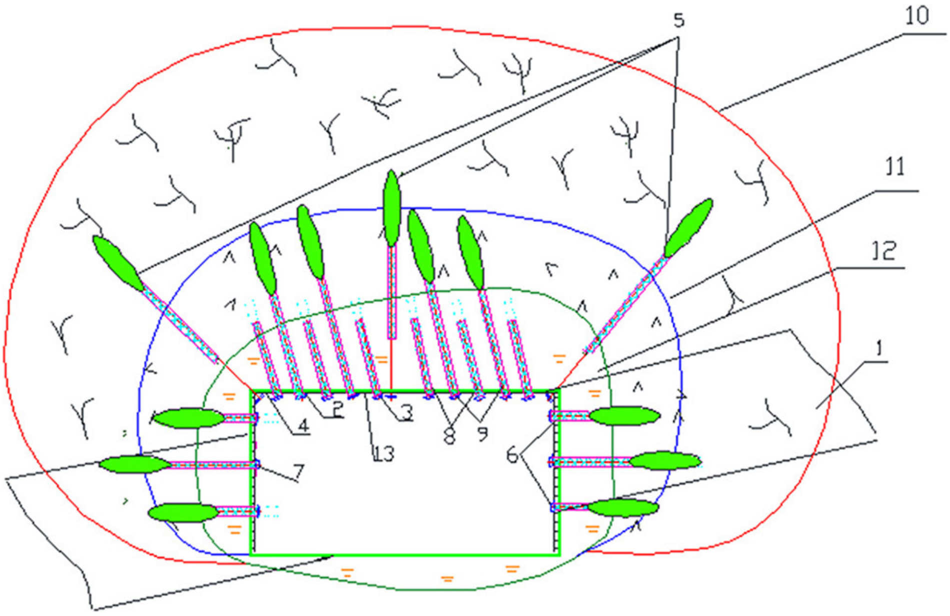



**Figure 3 – Application of single-level (a) and combined (b) schemes for supporting rocks of the roof of the mine**




1 – coal seam; 2 – pressure plate; 3 – tension nut; 4 – anchor mesh; 5 – deep rope anchors; 6 – fiberglass side anchors of the first level; 7 – fiberglass side anchors of the second level; 8 – steel polymer roofing anchors of the first level; 9 – steel-polymer roofing anchors of the second level (composite); 10 – zone of elastic deformations; 11 – zone of plastic deformation; 12 – reference pressure zone; 13 – the roof of the mine

**Figure 4 – Method of three-level (complex) fastening of rocks of the roof of a mine**

After the mortar has hardened, a pressure plate is put on the anchor, which is fixed with a nut and tension is made. A cone-shaped spacer installed between the strip and the plate with the tension nut, which, when the load is perceived, ensures the support compliance due to its deformation.

The advantages of this method are: the ability of the structure to perceive the load without delay, the large load-carrying capacity of the structure, the provision of obstacles to the displacement and stratification of roof rocks, the formation of domes and rock falls. The advantages of this method are also: a decrease in methane gas emission into the working cavity, an increased durability of the support and an increased overhaul life, as well as the achieved economic effect by reducing the cost of maintaining and repairing the mine [10].

An example of a specific application of the developed technological solution is presented on the passport for fastening the roof of the conveyor drift 61k12-z in the bearing pressure zone from the face of the Saranskaya mine (Karaganda coal basin, Republic of Kazakhstan) in the bearing pressure zone – Figure 5.

**Conclusions**

A study of the schemes of fastening side rocks of workings with various combinations of roof bolting has been carried out, on the basis of which it has been established that roof bolting is a means of improving the operational parameters of excavation workings with different physical, mechanical, strength and geometric parameters of the layers of the roof edge rocks.

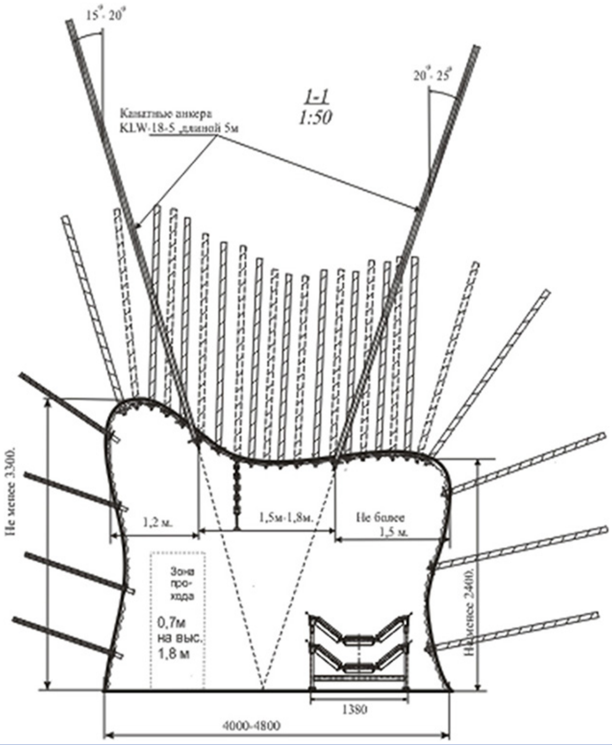



**Figure 5 – Passport of fastening the roof of the conveyor drift 61k$_{12}$-z of the Saranskaya mine in the bearing pressure zone**

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***Тау-кен өндірісінің айналасындағы массаның геомеханикалық күйіне екі деңгейлі бекітудің әсері***

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***Аңдатпа.*** *Қарағанды көмір бассейнінің шахталарында тау-кен қазбаларын анкермен бекітудің ерекшеліктері қарастырылған. Бүйірлік негізгі жыныстардың өзгеретін параметрлері бар қазба төбесінің екі деңгейлі бекітілуін пайдалану схемалары келтірілген. Сондай-ақ, жер бетінен қазбаның орналасу тереңдігіне байланысты әр түрлі тереңдікке арналған есептеулер келтірілген. Жұмыста шатырлы тау жыныстарын анкерлік көпірмен бекіту әдісі ұсынылған, оларды терең горизонттарда (600 м-ден астам) тұрақсыз тікелей төбесі мен бүйірі бар жыныстармен пайдалану үшін арналған. Осы шешімді қолданудың мысалы ретінде «Саран» шахтасының (Қарағанды көмір бассейні) лавасынан тірек қысым аймағында 61к$_{12}$-з конвейерлік штрек шатырын бекіту паспорты ұсынылды.*

***Кілт сөздер:*** *анкермен бекіту, тау-кен, стресстік күй, тау жыныстары, технологиялық схемалар, тау-кен және геологиялық жағдайлар, көму тереңдігі, бекітпе схемасы.*

***Влияние двухуровневого анкерного крепления на геомеханическое состояние массива вокруг горной выработки***

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***Аннотация.*** *Рассматриваются особенности применения анкерного крепления горных выработок на шахтах Карагандинского угольного бассейна. Также приведены схемы применения двухуровневого крепления кровли выработок с изменением параметров боковых вмещающих пород. Описаны расчеты для различной глубины заложения, в зависимости от глубины заложения выработок с поверхности. Представлен разработанный способ крепления пород кровли анкерным мостом для их использования на глубоких горизонтах (более 600 м) с неустойчивой непосредственной кровлей и боковыми вмещающими породами. В качестве примера применения данного решения представлен паспорт крепления кровли конвейерного штрека 61к$_{12}$-з в зоне опорного давления от лавы шахты «Саранская» (Карагандинский угольный бассейн) с применением данной технологии.*

***Ключевые слова:*** *анкерное крепление, горное дело, напряженно-деформированное состояние, горные породы, технологические схемы, горно-геологические условия, глубина залегания, схема крепления.*

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