термопластичного матеріалу, технологічного регламенту ізоляції поглинаючих горизонтів.

Ключові слова: *буріння свердловин, поглинаючий горизонт, промивальна рідина, поглинання, ізоляція, тампонажні матеріали, вибійне теплове джерело, термопластичні матеріали, розплав*

Цель. Повышение эффективности изоляционных работ за счёт применения термопластичных смесей на основе полиэтилентерефталата.

Методика. Поставленные задачи решались комплексным методом исследования, включающим анализ и обобщение литературных и патентных источников, проведение аналитических, экспериментальных исследований. Обработка экспериментальных данных проводилась на ПЭВМ с использованием методов математической статистики.

Результаты. Разработан и обоснован способ изоляции поглощающих горизонтов термопластичными материалами, для реализации которого необходимо выполнить следующие технологические операции: доставку термопластичных материалов на забой скважины, плавление термопластичных материалов и вдавливание термопластичных материалов в каналы поглощения. В качестве тампонажного материала для изоляции поглощающих горизонтов буровых скважин предложено использование бытовых отходов на основе полиэтилентерефталата.

Научная новизна. Впервые обоснована и доказана возможность применения в качестве тампонажного термопластичного материала бытовых отходов на основе полиэтилентерефталата. Впервые аналитически обоснована методика определения рациональной области применения технологии изоляции поглощающих и неустойчивых горизонтов термопластичными материалами с использованием забойных тепловых источников.

Практическая значимость. Состоит в разработке технологии и технических средств изоляции поглощающих и неустойчивых горизонтов, рецептуры тампонажного термопластичного материала, технологического регламента изоляции поглощающих горизонтов.

Ключевые слова: *бурение скважин, поглощающий горизонт, промывочная жидкость, поглощение, изоляция, тампонажные материалы, забойный тепловой источник, термопластичные материалы, расплав*

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TECHNOLOGY OF TWO-LEVEL SUPPORTING WORKING CONTOURS

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ТЕХНОЛОГІЯ ДВОРІВНЕВОГО КРІПЛЕННЯ КОНТУРІВ ГІРНИЧИХ ВИРОБОК

Purpose. Developing a technology with rope anchors hardening a roof of workings supported with steel-polymeric anchors which will exclude the roof collapse cases in zones of the increased mining pressure.

Methodology. Solving problems is based on systematic analysis and generalization of theoretic and industrial domestic and foreign experience in the field of development of technological schemes of mining roadways in stratified and ore mineral deposits; data modeling of strata pressure allocation, defectiveness and stability of rock massif; analytical researches of efficient application of technological innovations; experiments in real industrial conditions.

Findings. The two-level technology of supporting extraction workings based on accounting geomechanics of stressed-and-strained state of rocks around the workings with determining the optimum parameters of roof bolting depending on the influencing mining technological factors.

Originality of the methods proposed in the work consists in the following:

- the design capability to perceive loading without delays, a great load bearing capacity, prevention of the shift and stratification of the roof rocks, formation of domes and rock inrushes;
- reducing methane gas emission into the working, enhanced durability of the support and increased between-repairs resource, as well as the reached economic efficiency due to the cost reduction for working support and repair.

Practical value. Depending on the characteristic of the roof rocks, a way of supporting the roof rocks is developed with an anchor bridge.

Keywords: *workings, geomechanical processes, roof bolting, manifestations of mining pressure, stability of rock outcrops, mining factors, stressed-and-strained state, coal-rock massif, convergence*

Introduction. The current tendency of using a nonpillar technology of developing seams requires searching well-tried remedies of protecting preparatory workings, first of all adjoining the stope.

Manifestation of technological factors is caused by the development depth, the direction and speed of driving the preparatory faces, ways of driving and protecting, types of support and the technological scheme of supporting workings.

When analyzing the practice of using extraction workings, it is necessary to refer to the major mining-and-geological factors influencing the conditions of their driving and supporting; the depth of bedding determining the value of vertical and horizontal components of mining pressure; the seam thickness and inclination; the enclosing rocks properties.

Defining the main problem. The amount of implementation of the roof bolting of workings in mines of the Karaganda coal basin makes 12 % in the pure form and 42 % in the mixed form. For a broader use of the roof bolting, it is necessary to substantiate its parameters depending on the development conditions, to determine the area of possible and effective operation and to develop progressive technological schemes of its construction.

Analyzing the study results. The main reasons of limited volumes of using roof bolting of workings are:

- complication of mining-and-geological and mining conditions with transition to the development depth of over 600 m;
- the cross-sectional area of workings, in particular technological schemes of extraction adjoining workings increased by 35–40 %;
- insufficient study of geomechanical processes in the rocks around workings at the low levels and working capacity of roof bolting in these conditions.

When supporting the roof rocks of a working, there can be contour mining rocks of various physical-and-mechanical, strength and geometrical parameters of seams.

At this, stratifications and zones of crack forming can locate at various distances from the working contour.

In the zone of the stop influence various schemes of support can be used depending on the characteristics of the roof rocks: a single- or two-level and a combined scheme of fastening.

Presentation of the main research. The predicted depth of slipping the mining rocks subjected to compression across the seams is in accordance with the provided calculation scheme from the expression [1]

$$C = \left(\frac{K_c \gamma H B}{100\sigma_{\bar{i}}} \cos\frac{a}{2} - 1 \right) h \,\mathrm{tg}\frac{90^\circ - \varphi}{2}, \qquad (1)$$

where C is the depth of coal or rock slipping in the seam or rock workings, m; K_c is the coefficient of concentration of compressing stresses in the heels of the set of natural balance connected with the working driving; it is selected depending on the way of driving, form and ratio of the cross dimensions of the working; for obtaining the depth of the mining rocks slipping at the interfaces of workings, the K_c values increase by 1.4 times; γ is the average density of the rocks lying over the working to the surface, t/m^3; H is the working laying depth from the surface, m; B is the coefficient of stoping influence for seam and rock workings constructed out of the zone of stope influence [2]; α is the rocks inclination, degrees; σ_n is the average durability of the compressed thickness of rocks h cut by the working, MPa; if a rock layer that is weaker in its bearing capacity occurs in the compressed thickness, its compression strength is taken in calculations; h is the thickness of the compressed layers of rocks cut by the working, m.

If the cut massif has diverse rocks of different durability, the thickness of the weakest pack of rocks which is contained in h limits is understood as the thickness of a layer (layers); σ is the seeming angle of internal friction of rocks cut by the working, degree.

At a considerable difference of strength properties of the rocks cut by the working the σ values are selected according to the weakest pack of rocks within h. The dependence of the seeming angle of internal friction of rocks on their compression strength is expressed by the equation

$$\sigma = \mathrm{arctg}\,\sigma_n/10;$$

$$\sigma = \mathrm{arctg}\,24/10 = \mathrm{arctg}\,2.4 = 67. \qquad (2)$$

Choice of K_c as the coefficient of concentration of compressing stresses in the heels of the set of natural balance connected with the working driving is made ($K_c = 1.5$) depending on the way of driving, form and ratio of the working cross dimensions. To obtain the depth of the mining rocks slipping at the interfaces of workings, the K_c values are increased by 2–3 times (respectively 1.5 * 2 = 3 and 1.5 * 3 = 4.5).

Depending on the working laying depth, the calculations are given for various depth of laying (H = 600, 700 and 800 m).

Depending on the average durability of the compressed rock mass (σ_n), MPa, it is taken to be 10, 15 and 24 MPa. The working depth at the average durability of rocks of 24 MPa is determined; at the depth of laying 600, 700 and 800 m it makes respectively 0.05–1.2, 0.09–1.5 and 0.19–1.8 m.

The working depth at the average durability of rocks of 15 MPa is determined. With the depth of laying of 600, 700 and 800 m it makes respectively 0.35–2.28, 0.5–1.64 and 0.67–3.25 m.

The working depth at the average durability of rocks of 10 MPa is determined. With the depth of laying of 600, 700 and 800 m it makes respectively 0.83–3.7, 1.08–4.4 and 1.32–5.1 m.

The design data show that with increasing the coefficient of concentration of compressing stress (K_c) and reducing the average durability of the compressed rock mass (σ_n), the depth of the rocks slipping *C* increases, m (Fig. 2).

At the maximum coefficient of concentration (K_c = 4.5) and the minimum durability of rocks (δ_n = 10 MPa), the depth of the working reaches the highest point, 5.1m.

The working laying depth also plays an important role since the depth of the rock slipping also increases with its growth (Fig. 1). According to this, it is possible to use single-level (Fig. 2, *a*), two-level and combined (Fig. 2, *b*) schemes of supporting the working rocks.

1. Zone 1 (hardening zone of resin-grouted roof bolt roof anchors); 2. Zone 2 (hardening zone of the cable anchors); 3. Zone 1 Zone hardening compounds (hardening of the roof area of resin-grouted roof bolanchors) and Zone 2 (cable anchors hardening zone); 4. The cable anchor; 5. Resin-grouted roof bolt anchor; 6. Zone of maximum hardening compound 1 and Zone 2

The developed technique of supporting the roof rocks with an anchor bridge for use at deep levels of coal mines (over 600 m) with an unstable immediate roof and side enclosing rocks is given below.

The task of a technical solution is increasing stability of the immediate roof at unstable sites of workings, increasing safety of carrying out operations at deep levels by means of lacing together unstable rocks of the immediate roof and subsequent fixing of the developed artificial "bridge" to hard rocks of the main roof.

The technical result provides improving the technical condition of the roof bolting, developing the conditions for supporting the fixed section of the working, ensuring the greatest stability of the immediate roof, reducing rock inrushes and increasing the support service life owing to the fact that the artificially seamed immediate roof acquires the additional margin of safety in the zone of basic pressure and the formed massif of rocks is supported by means of rope anchors of deep bedding to

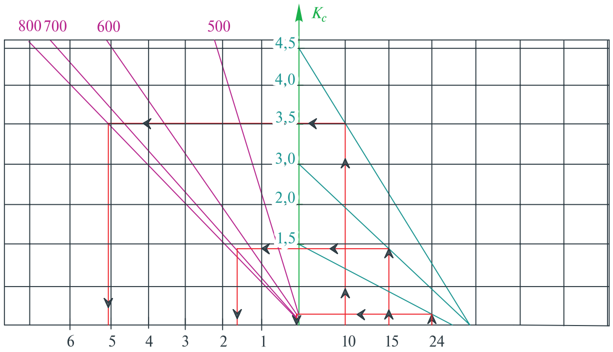

Fig. 1. Computation chart for determining the rock slipping

harder rocks of the main roof provided by steady hard rocks, such as soapstone or sandstone, thereby an effect of strengthening the working contours and decreasing mining pressure on the support is created (Fig. 3).

This connection is performed by means of mounting 3 levels of anchors: level 1 anchors (they are superficial to support the immediate roof), deep anchors of level 2 (they form connection between the immediate roof supported by level 1anchors and the main roof) and anchors of deep laying that represent a rope anchor not less than 5–7 m long. For supporting the first level steel-polymeric anchors 2.4 m long are used, and for supporting the second level steel-polymeric anchors 3.5 m long are used (compound anchors).

Around the working there are 3 zones formed: a zone of basic pressure, a zone of elastic deformations and a zone of plastic deformations. Supporting the working begins with the face frill, namely the roof and the sides of the working. Then the level 1 roofing anchors with complete filling are mounted. After this the level 2 roofing anchors and the side anchors also with complete filling are mounted. Further on, the rope anchors of deep

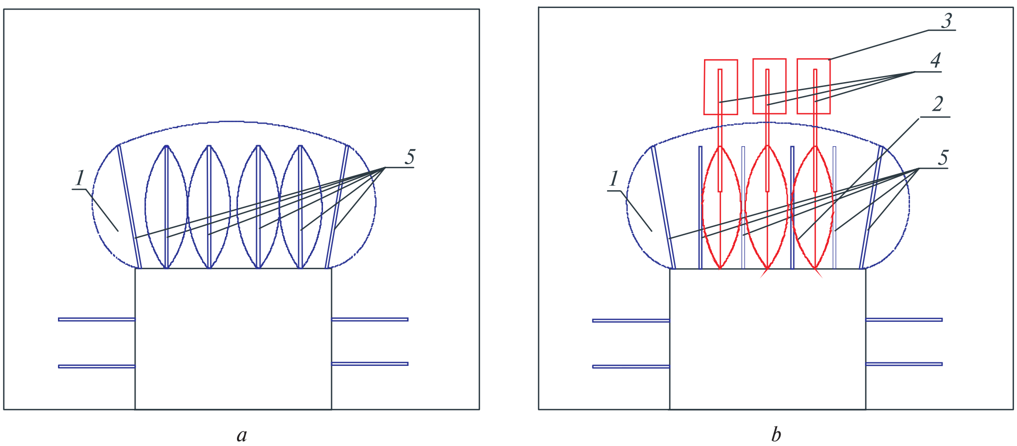

Fig. 2. Using single-level (a) and combined (b) schemes of supporting the working roof:

1 – coal seam; 2 – clamping plate; 3 – tension nut; 4 – anchor grid; 5 – rope anchors of deep laying; 6 – glass-plastic side anchors of level 1; 7 – glass-plastic side anchors of level 2; 8 – steel-polymeric roof anchors of level 1; 9 – steel-polymeric roof anchors of level 2 (compound); 10 – zone of elastic deformations; 11 – zone of plastic deformations; 12 – zone of bearing pressure; 13 – working roof

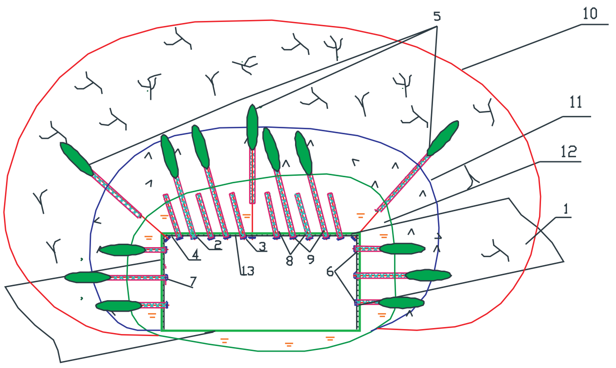

Fig. 3. Method of three-level (complex) supporting of the working roof rocks:

1 – coal seam; 2 – clamping plate; 3 – tension nut; 4 – anchor grid; 5 – rope anchors of deep laying; 6 – glass-plastic side anchors of level 1; 7 – glass-plastic side anchors of level 2; 8 – steel-polymeric roof anchors of level 1; 9 – steel-polymeric roof anchors of level 2 (compound); 10 – zone of elastic deformations; 11 – zone of plastic deformations; 12 – zone of bearing pressure; 13 – working roof

laying with incomplete filling of the shot are mounted. All the anchors are fixed in the shot with a solution obtained when the anchor breaks the capsules which are fed into the shot in advance. The number of shots is defined by the passport of the face supporting.

After the solution has solidified, a clamping plate, which is fixed by a tension nut, is put on the anchors. Between the strip and the plate with a nut, a cone-shaped spacer is set which when perceiving the load provides the support pliability owing to its deformation.

The benefits of this method are: the design capability to perceive loading without delays, a great load bearing capacity, prevention of the shift and stratification of the roof rocks, formation of domes and rock inrushes. The benefits of this method also include reducing methane gas emission into the working, the increased support durability and the increased between-repairs resource, as well as the reached economic efficiency owing to reducing the cost to maintain and repair of the working [3, 4].

An example of the particular application of the developed technological solution is presented in the passport of supporting the roof of $61k_{12\text{-}3}$ belt horizon in the zone of bearing pressure from the lava of Saranskaya mine (the Karaganda coal basin, the Republic of Kazakhstan) – Fig. 4.

Trial mounting of experimental rope anchors of the KSTU design was carried out at Kostenko mine [5].

Within the trial operation of the mounted experimental rope anchors of KSTU production in $44к_{10\text{-}3}$ belt heading and $49k_{7\text{-}3}$ ventilating horizon a pilot batch of rope anchors in the number of 100 pieces was tested.

As a result of testing the experimental rope anchors (KSTU production) it was established that:

- the design of the trial batch of rope anchors is convenient and safe to use for the working roof inhaling;

- the trial operation of rope anchors was made on the interfaces of the preparatory faces. Within the operation the experimental anchors showed a good bearing capa-

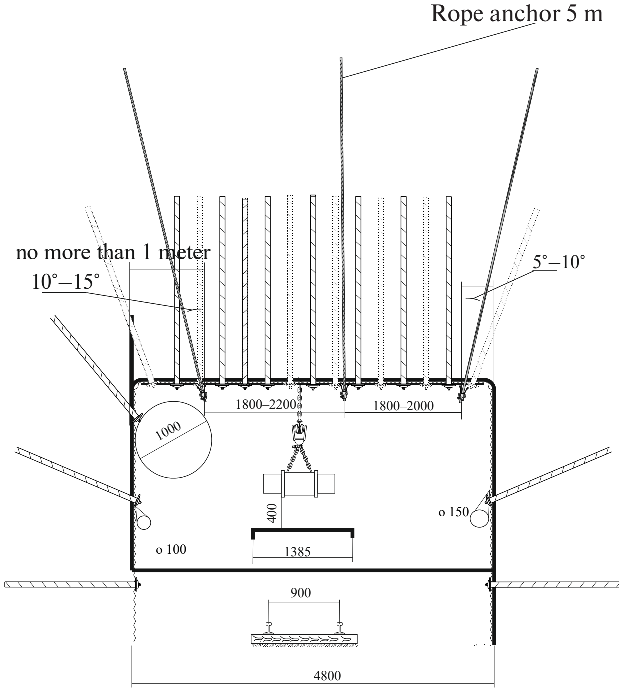

Fig. 4. Passport of supporting the roof of the $61к_{12\text{-}3}$ belt heading of Saranskaya mine in the zone of bearing pressure

bility, not being inferior to the designs of foreign rope anchors.

Rope anchors were mounted ahead of the zone of bearing pressure with the combined supporting of workings on $к_7$ seam.

Conclusions. There was performed supporting of the gap zone between the linear sections of self-propelled support and the heading zone using steel-polymeric and rope anchors that would permit to strengthen rocks of this zone that in turn would provide stability of rocks in the roof and would reduce material consumption and labor costs for re-supporting the zone of the gap. 10–15 m ahead of the lava "strings" of running of SVP-22(27) $L = 2.0–2.5$ m are installed with mounting for the running a prop GVKU (ST-20) 1 with a step of 1 m.

Schemes of supporting side rocks of the working with various combinations of roof bolting were studied, on the basis of which it was established that the roof bolting is a means of improving the operational parameters of extraction workings at various in physical-and-mechanical, strength and geometrical parameters of layers of the roof contour rocks.

The technology is realized which uses rope anchors to strengthen the roof of workings supported with steel-polymeric anchors that excludes roof collapse cases in zones of the increased mining pressure. The influence of the two-level anchor supporting on the geomechanical conditions of the massif around the working is assessed. The two-level technology of supporting extraction workings is proposed based on the accounting the geomechanics of the stressed-and-strained state of rocks around workings with determining the optimum parameters of the roof bolting depending on the influencing mining technological factors. It will exclude or as far as possible will reduce the danger of excessive concentration of stresses in the contour parts of the massif based on the determined consistent patterns of zones of mining pressure manifestation in coal-rock massif taking into account mining technological conditions of the development.

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Мета. Створення технології зміцнення канатними анкерами покрівлі виробок, закріплених сталеполімерними анкерами, що виключать випадки обвалення покрівлі в зонах підвищеного гірського тиску.

Методика. Полягає в розробці способів кріплення порід покрівлі анкерним мостом на глибоких горизонтах вугільних шахт (понад 600 м) з нестійкою безпосередньою покрівлею й бічними породами, що вміщають.

Результати. Створена дворівнева технологія кріплення виїмкових виробок на основі врахування геомеханіки напружено-деформованого стану порід навколо виробок з визначенням оптимальних параметрів анкерного кріплення в залежності від гірничо-технологічних факторів, що впливають.

Наукова новизна. Полягає в наступному:

- здатність конструкції без затримки сприймати навантаження та її велика вантажонесуча здатність, забезпечення перешкоди зміщенню й розшаруванню порід покрівлі, утворення куполів і вивалів породи;

- зменшення газовиділення метану в порожнину виробки, підвищена довговічність кріплення та збільшений міжремонтний ресурс.

Практична значимість. У залежності від характеристики порід покрівлі розроблено спосіб кріплення порід покрівлі анкерним мостом.

Ключові слова: *гірничі виробки, деформаційні процеси, геомеханічні процеси, анкерне кріплення, гірський тиск, стійкість породних оголень, гірничотехнічні фактори, вуглепородний масив, конвергенція*

Цель. Создание технологии упрочнения канатными анкерами кровли выработок, закрепленных сталеполимерными анкерами, которые исключат случаи обрушения кровли в зонах повышенного горного давления.

Методика. Заключается в разработке способов крепления пород кровли анкерным мостом на глубоких горизонтах угольных шахт (более 600 м) с неустойчивой непосредственной кровлей и боковыми вмещающими породами.

Результаты. Создана двухуровневая технология крепления выемочных выработок на основе учета геомеханики напряженно-деформированного состояния пород вокруг выработок с определением оптимальных параметров анкерного крепления в зависимости от влияющих горно-технологических факторов.

Научная новизна. Заключается в следующем:

- способность конструкции без задержки воспринимать нагрузку и ее большая грузонесущая способность, обеспечение препятствия смещению и расслоению пород кровли, образованию куполов и вывалов породы;

- уменьшение газовыделения метана в полость выработки, повышенная долговечность крепи и увеличенный межремонтный ресурс.

Практическая значимость. В зависимости от характеристики пород кровли разработан способ крепления пород кровли анкерным мостом.

Ключевые слова: *горные выработки, деформационные процессы, геомеханические процессы, анкерная крепь, горное давление, устойчивость породных обнажений, горнотехнические факторы, угле-породный массив, конвергенция*

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