Код МРНТИ 52.13.23

A. Zhumabekova, *E. Khalikova, D. Meiram, D. Syzdykbayeva
Abylkas Saginov Karaganda Technical University (Karaganda, Kazakhstan)

SCIENTIFIC-TECHNICAL ACHIEVEMENTS ANALYSIS AND INDUSTRIAL EXPERIENCE IN STRENGTHENING EXCAVATION WORKINGS

Abstract. The experience of coal and mining enterprises, the development of underground mines shows that it is an important task of industrial activity to ensure the reduction of defects in mine contours. With the «supportless» technology and the frame structure of excavations, there are intractable problems of safety and complexity of work in the areas of long preparation works, including high-performance, where they come into contact with cleaning surfaces. In this case, the initial section of the grooves adjacent to the cleaning surfaces is usually 14-16 m^2, and the second section – 9-10 m^2. This not only makes predictions of gas-dynamic phenomena, ventilation systems and layer accumulation of methane in difficult ventilated working areas but also complicates the placement of modern large-sized equipment with high unit power, its transportation to a new location, worsens the situation. Exchange of jobs of people and organization of their delivery, transportation of materials create a constant high-risk situation.

Key words: *zone of manifestation of increased rock pressure, fastening, support pressure, unit power, technology, methane, minerals, transportation of materials, large equipment.*

Қазба жұмыстарында тау жыныстарын нығайтудағы ғылыми-техникалық жетістіктер мен өндірістік тәжірибені талдау

Аңдатпа. Көмір және тау-кен өндіру кәсіпорындарын, жер асты қазбаларын игеру тәжірибесі кен қазбаларының контурларының ақаулығын азайтуды қамтамасыз ету өндірістік қызметтің маңызды міндеті болып табылатынын көрсетеді. «Тірексіз» технологиямен және қазбалардың рамалық құрылымымен дайындық жұмыстарының ұзын, оның ішінде жоғары өнімді, тазалау беттерімен түйісетін аймақтарында шешілмейтін қауіпсіздік және жұмыстың күрделілігі мәселелері туындайды. Бұл жағдайда тазарту беттеріне іргелес жатқан ойықтардың бастапқы қимасы, әдетте, 14-16 м^2, ал екінші секция – 9-10 м^2 аспайды. Бұл қиын желдетілетін жұмыс аймақтарында газ-динамикалық құбылыстардың, желдету жүйелерінің және метанның қабат жинақталуының болжамдарын жасап қана қоймайды, сонымен қатар бірлік қуаты жоғары заманауи үлкен өлшемді жабдықты орналастыруды, оны жаңа жерге тасымалдауды қиындатады, жағдайды нашарлатады. Адамдардың жұмыс орнын айырбастау және оларды жеткізуді ұйымдастыру, материалдарды тасымалдау – бұл тұрақты жоғары қауіптілік жағдайын туындайды.

Түйінді сөздер: *тау жыныстарының қысымының жоғарылауының көрініу аймағы, бекіту, қолдау қысымы, бірлік қуат, технология, метан, пайдалы қазбалар, материалдарды тасымалдау, ірі жабдықтар.*

Анализ научно-технических достижений и производственного опыта при упрочнении в выемочных выработках

Аннотация. Опыт разработки угольных и горнорудных добывающих предприятий, полезных ископаемых, отрабатываемых подземным способом, показывает, что обеспечение снижения дефектности контуров горных выработок является важной горно-технической задачей производственной деятельности. При бесцеликовой технологии и рамном сооружении выработок возникают неразрешимые проблемы безопасности и трудоемкости работ в зонах сопряжения подготовительных выработок с длинными, в том числе высокопроизводительными, очистными забоями. При этом первичное сечение выработок, примыкающих к очистным забоям, как правило, не превышает 14-16 м^2, а вторичное сечение – 9-10 м^2. Возникает проблема не только газодинамических явлений, систем проветривания и слоевых скоплений метана в труднопроветриваемых зонах выработок, появляются затруднения в размещении современного крупногабаритного оборудования большой единичной мощности, его передислокации, ухудшаются условия для перемещения людей и организации их доставки, транспортировки материалов, что создает ситуацию постоянной повышенной опасности.

Ключевые слова: *зона проявления повышенного горного давления, крепление, опорное давление, единичная мощность, технология, метан, полезные ископаемые, транспортировка материалов, крупногабаритное оборудование.*

Introduction

Implementation of the task of improving the establishment and maintenance of production facilities is an important factor in increasing the efficiency of mineral production in mining. The need to carry out these works is connected with the unsatisfactory working conditions of more than 50 percent of the Karaganda coal basin.

The weakest point in solving the problems of increasing the efficiency of the use of roof bolting is the insufficient study of geomechanical processes in the vicinity of mineral deposits. Anchors perform the main functions of tying weaker rocks in the overburden to stronger rocks, connecting layered rocks into a single support structure with high bending resistance, increasing friction between rock layers, and absorbing tensile stresses in the overburden. However, the effective use of anchor technology depends on the conditions of its use, which are determined by mining geological and mining technical factors.

It was found that the methods of calculating the parameters of mining pillars cannot always ensure the reliable preservation of mining excavations in the area of influence of cleaning operations. To determine the parameters of the anchor base and to make reasonable technological decisions to ensure its effective operation, a geomechanical forecast of the stress-deformation state of rocks is required, which forms the main massif of mining production.

Therefore, the development of technological means and systems for effective approval of preparatory work is an important task in the field of mining.

Full-scale experimental and analytical studies were carried out, technological schemes of strengthening mines with roof bolting were formed taking into account the development of deformation processes to reduce the costs of conducting and maintaining underground mines and to achieve the minimum failure of working circuits during the operation of mining enterprises.

To achieve this goal, the following tasks were solved in the monograph: mining inspections were carried out on the condition of the excavation works, which passed near the geological faults of the Kostenko mine, and were fixed with an anchor support; the shift of the rock chain near the ore deposits of the Saranskaya mine of the CD «Qarmet» JSC was studied; the effect of main stresses on the stability of mineral deposits was determined; models for calculating the stability of ores based on anchoring parameters were determined; the results of studies on the improvement of technological schemes of industrial testing of technical solutions developed in the case of mines of the CD «Qarmet» JSC were included; production experiments were carried out in the Kostenko mine of the CD «Qarmet» JSC; technological developments were implemented in the mining and geological conditions of the mines of the CD «Qarmet» JSC; progressive tools were created and fixing

parameters were determined during work in areas of geological disturbances, in areas of high rock pressure, at the same time, work was carried out to determine the parameters of protection of works in the areas affected by mining operations and carry out technical and economic evaluation of technological solutions.

Materials and Methods

Fulfillment of the research objectives is the use of full-scale experiments and numerical modeling data evaluation methods to form a two-level technology of mineral fixation in the case of underground deposits; the analytical modeling of stress-strain states; the feasibility assessment of technological developments carried out by conducting industrial experiments in mining conditions.

Currently, three types of anchors are used in the mining industry: mechanical anchors, anchors fixed with cement along their entire length, and anchors fixed with polymer, among them, anchors fixed with polymer along their entire length are widely used in the mines of the Karaganda basin. Mechanical anchors, especially lock anchors, are not used in coal mines because over time their anchorage weakens as the roof sags downward. The use of polymer-reinforced anchors in the mining industry is limited by the high cost of the resin. The feasibility of their use is determined by the quick drying time and the preservation of newly covered roof rocks, especially weak and flooded rocks. Full-length cemented anchors are inexpensive and technically suitable for use in coal mines [1].

Anchors ensure uniform loading of the support plate, at angles the anchor deviates from normal to the roof by 200, and their initial tension during anchor mounting is 45-55 kN, which prevents overlapping of the anchored roof.

The roof bolting should be used in the following mining and geological conditions [2]: in layered rocks with weak connections between layers (in this case, anchors attach several layers to a strong slab, where the process of crack formation is much weaker than individual separated layers); if there are excavations of weak rocks with a thickness of 1.5-2.0 m directly on the roof, a thick layer of strong rocks lies on top of it (in this case, a weak roof is fixed on top of the main roof). When located in a thick, weakly fractured massif of homogeneous rocks, an anchorage is used. In this case, the anchor support strengthens the attraction of rocks to each other, increases their strength and stability and prevents the development of a collapse arc; in the presence of weak, cracked rock, anchors are mounted with holders and stiffeners. The supports are made of metal strip, channels, special profile or welded from round rods. In the short life of the work, as well as wooden anchors, wooden supports made of beams, boards and saws are also used.

Active roof control systems can be achieved by combining different types of roof fixings. Thus, an anchor tube *(1)* and ampoules with a quick-setting mixture are mounted in the drilled hole, and the anchor iron tube is fixed with a quick-setting mixture *(2)* along a length of 1.0-1.2 m, and a high-strength metal pin *(4)* is attached to the monolithic mass, which a supporting plate *(5)* is placed on it from below and pressed against the roof rocks with a nut *(6)* (Figure 1).

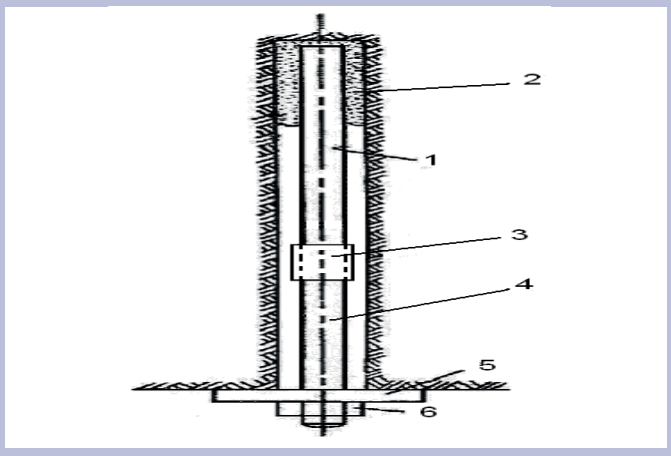

Figure 1. Flexible anchor: *1 – anchor iron pipe; 2 – quick-solid mixture; 3 – clutch; 4 – metal bolt; 5 – support plate; 6 – nut.*
Сурет 1. Икемді анкер: *1 – анкерлік темір түтік; 2 – тез қататын қоспа; 3 – муфта; 4 – металлдан жасалған болт; 5 – тіреуіш плита; 6 – гайка.*
Рис. 1. Податливый анкер: *1 – анкерный стержень; 2 – быстротвердеющая смесь; 3 – муфта; 4 – металлический болт; 5 – опорная плита; 6 – гайка.*

This action results in a better fit of the rock with the reaction curve. Shifts, bending and sliding may occur in the mechanical bolt area, but the stability of the production is not compromised. Therefore, in mines and quarries, they try to mount the anchor post in the mine as soon as possible so that the anchor iron tube is loaded when the rock is moved.

A passive full-contact anchor support is as follows: the anchor core is fixed along the entire length of the hole. The anchor iron tube is attached to the opening by means of ampoules with a quick-setting mixture or by injecting a quick-setting solution (mixture).

Steel-polymer anchors fixed along the entire length of the hole by the ampoule method of supplying the hardening mixture have a high load-bearing capacity (120 kN and more) [3-7]. Such polymer-sized additives are often used despite their high consumption and cost. To reduce the consumption of the polymer mixture, the diameter of the hole is reduced to 25-32 mm. The characteristics of the anchor are rigid, so attempts are made to equip it with elements of flexibility [8, 9].

Results

There is a real possibility that steel-polymer anchors, which use an effective method of injecting a chemical mixture into the hole, are technically more advanced than ampoules, because the injection of the chemical mixture allows increasing its permeability to the hole rock. The strength of the anchorage is the effect of chemical strengthening of rocks by filling cracks around the rock massif, and in this case, the probability of leakage of the chemical mixture is reduced [10-12]. However, it is necessary to use a special set of equipment to inject the chemical mixture into the hole where the anchor iron tube is mounted. The use of this set of equipment is technologically complicated by the presence of a contact zone between the chemical components (in the area of the mixer) during the

transition from hole to hole (mounting of the chemical mixture, cleaning of the nozzle in the mixer) and the difficulty of mounting a seal at the mouth of the hole with limited dimensions of the latter (simultaneous placement of the anchor, delivery pipe and elasticity).

Reinforced concrete anchors are attractive for the type of composite materials used and provide the best possible load-bearing capacity, and are widely popular in certain fields of application in the mining industry and construction. The anchor is made of reinforcement (a rod, usually with a periodic profile, parts of ropes are used, a pipe with a diameter of 6-12 mm, a wire twisted into a thread), inserted into a well or a hole; sand cement solution to water or liquid glass with hardening accelerators and mass expansion additives or phosphogypsum or magnesium solution; sealing ring; a gathering and fastening device in the form of a nut on a screw or bent loop, a rod in a wire or cable hook. Reinforced concrete anchors are divided into ampoules and injection during solution injection after mounting the fittings in the well [10]. The main disadvantages that prevent the widespread use of anchors with mineral binder in coal mines and mines are the problem of long-term increase in strength and the efficiency of mounting technology with a limited batch of anchors mounted in one anchor cycle. It is clear that the greatest effect of reinforced concrete anchors in coal mines is achieved when supporting the excavation soil (to combat uplift), when mounting large batches of anchors from the surface (outside the surface space) (the area where a set of mining equipment is located, closely related to cyclic mining operations). In the latter case, we mass-produce a fixed batch of anchors: the requirements for the rate of increase in strength are reduced, and defective anchors do not significantly affect the performance of the technology.

Reinforced concrete anchors are characterized by very high fixing strength. They are able to create a solid «rock-support» system and absorb large compressive and tensile loads [10-12].

Reinforced concrete anchors include anchors that consist of a rod and fixing cement or sand-cement mortar. They can be unstressed or prestressed. During the mounting of reinforced concrete anchors, cement solution is pumped into the hole by means of a pump [10]. The liquid is filled from the bottom of the pit to its mouth mounted manually or with a hydraulic or pneumatic hammer. This action creates a problem when mounting an anchor on the roof of the excavation, because it is necessary to wait up to 8 hours for the poured liquid to dry.

The hardening time of the cement solution can be significantly reduced. When the rod is inserted into the hole as shown in Figure 2 a, b, the cartridge bursts in the water capsule and the cement gets wet. Wet cement mortar fills the entire gap and is quickly fixed in a few seconds and has the required density within 5 minutes.

In paper [11], a mineral-based composition is recommended for fixing the anchor rods, which ensures a strong fixing of the anchor for 10 minutes. The authors conducted research to determine the technological parameters of mineral-based ampoules of ACD and checking their productivity in the mines of the Karaganda basin. The industrial introduction of ACD ampoules made it possible to increase work safety during mining operations.

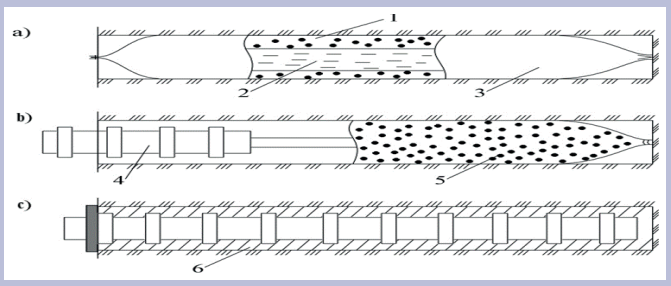

Figure 2. Mounting a reinforced concrete anchor on the basis of a cement mixture: *a) – cement cartridge in a spur, b) – inserting an anchor rod into the chuck, c) – construction of the anchor; 1 – cement, 2 – aqueous capsule, 3 – cartridge outer shell, 4 – anchor rod, 5 – mixing the mixture, 6 – solid cement mixture.*

Сурет 2. Цемент қоспасы негізінде темірбетонды анкерді орнату: *а) – шпурдағы цементті патрон, б) – патронға анкерлік штанганы енгізу, в) – анкердің құрылысы; 1 – цемент, 2 – сулы капсула, 3 – патронның сыртқы қабығы, 4 – анкерлік штанга, 5 – қоспаны араластыру, 6 – қатқыл күйдегі цемент қоспасы.*

Рис. 2. Установка железобетонного анкера на основе цементного раствора: *а) – цементный патрон в шпуре, б) – введение в патрон анкерной штанги, в) – конструкция анкера; 1 – цемент, 2 – водяная капсула, 3 – оболочка патрона, 4 – анкерная штанга, 5 – перемешивание раствора, 6 – затвердевший цементный раствор.*

Steel-polymer anchors have been widely used in the practice of fixing ores. The principle of operation of these anchors is mounting a cartridge with artificial resin and hardener on the spur (see Figure 3).

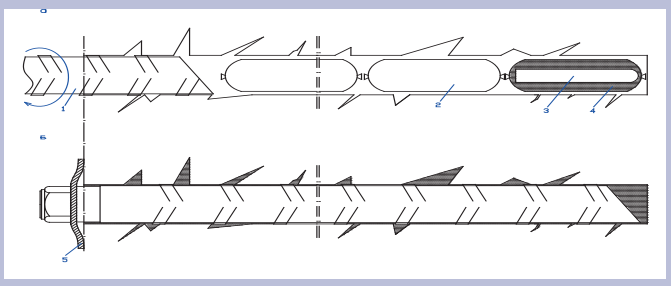

Figure 3. Start and finish diagram.
Сурет 3. Бастау және аяқтау схемасы.
Рис. 3. Схема начала и завершения.

Reinforced concrete anchors have achieved particular success when strengthening rocks, where the anchor depth is 10-20 m and more, the length of the concrete locking part is 3-4 m, the diameter of the wells is 100-120 mm, the pretension of the ropes (rope bundles) is 400-1400 kN.

Discussion

The main disadvantage of fixing reinforced concrete is that the anchor does not work until the cement mixture hardens. This can be eliminated if a lock is added to the anchor structure, which is initially able to hold the anchor rod in the well

with its end. Full-length cemented anchors have the following advantages:

- high concentration of stresses in the anchor holes is not allowed, thus allowing the use of this type of anchors in weak rocks;

- the anchor is effective against the movement of rocks both in the direction of the pit axis and perpendicular to it;

- the resistance of anchors to shear loads is greater than that of anchors fixed with the end part.

But they are not very flexible, and even if the support plate is nailed firmly to the roof rock with a nut, only the plate and the part of the anchor rod adjacent to the plate are active. This design prevents settlement of the roof rock so that stresses are concentrated at the rock contact. When the stresses exceed the strength characteristics of the rock in contact, the latter collapses and spills, and the anchor iron tube is exposed between the slab and the roof.

The passive type is the screw anchor, because it receives the axial load only after the roof rocks have shifted.

Screw anchors are mounted in pre-drilled holes, and the diameter of these holes is smaller than the outer diameter of the screw. Wells are drilled with cutters with a diameter of 26-27 mm, so when the screw anchor is inserted into the well, it is inserted into the rock as an engraving.

During the testing of screw anchors, certain shortcomings were revealed [12], that is, screw anchors were not suitable for mounting in such rocks as carvings.

The twisting of the anchors is limited by the intersection of solid inclusions found in the rocks, because the amount of resistance of the screw anchors increases significantly when such twisting occurs.

Screw anchors are used in potash mines with plastic rocks. Due to the difficulty of mounting in hard rock, they are rarely used in coal mines. They are not used in mines where the rock strength in the roof exceeds 120 MPa.

The «Swellex» and «Split-Set» friction anchors are of special interest. «Swellex» is a deformable tube that is expanded to the shape of the hole by water pressure and forces to fix the unit length of the hole. It takes effect immediately after mounting. Their mounting causes a reduction in the length of the rod, which contributes to the pressing of the base plate against the roof rocks in the mine. The loading of the Swellex array with an anchor has its own form (Figure 4, a) and this form is very similar to an anchor of the end type and cemented along the length of the spur. But compared to the latter, it has an indisputable advantage: «Swellex» can slide along the hole without losing its load-bearing capacity under high mountain pressure, that is, «Swellex» is a flexible anchor. But during long-term use of this anchor, problems with corrosion of the metal pipe arise. «Swellex» anchors are used only where the service life is not long.

«Split-Set» friction stabilizer anchor is widely used in the US mining industry. As the split core is forced into the hole, the spring action of the compressed pipe exerts a radial force on the rock and creates a frictional resistance to the sliding of the rock on the metal. It loads axially and radially along the entire length of the joint contact (Figure 2 b). The radial directions of the forces on the walls of the pit are estimated to be 3.5 kg/cm^2.

Such active loading of the rock with the «Split-Set» stabilizer creates a peculiar pear-shaped load distribution in the mass of the roof [12]. The lower part of the pressure «pear» is located directly under the slab, and along the entire length of the anchor's contact with the rock, a cylindrical column of rock compression is formed. Due to the triaxial load in this area, the strength of the rock and its stability increase significantly.

When mounting a stud, the rod slides into the hole without being loaded to the point of failure. Then, as the rock compressive forces (displacement) appear, the anchorage increases with time and tends to match the rock compressive load response curve with the adjustment of internal stresses.

Integrated or specialized anchors allow efficient controlling the roof. By combining different types of supports, active roof control systems can be achieved, as the mechanical bolt of the combined support is not connected to the stone by the quick-setting mixture, which reduces the stiffness modulus of the system and allows the stone to move around the rock and to some degree «breathe».

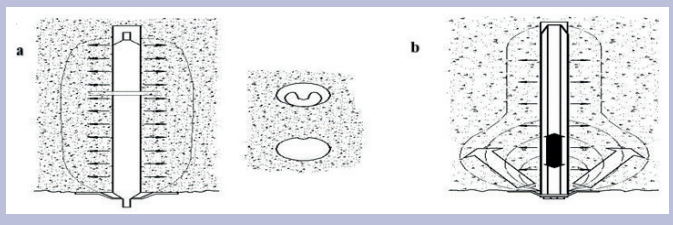

Figure 4. «Swellex» *(a)* **and loading diagram of «Split-Set» systems** *(b).*
Сурет 4. «Свеллекс» *(а)* **және «Сплит-Сет» жүйелерінің жүктеу диаграммасы** *(б).*
Рис. 4. Эпюра нагружения систем «Свеллекс» *(а)* **и «Сплит-Сет»** *(б).*

This allows the bolt hole to place more stress on the base plate and to cause uplift stress within the rock massif. In this case, the load on the base plate should not exceed 50% of the yield strength of the bolt steel. Excessive initial load on the base plate can cause dangerous situations, for example: sudden rupture of the anchor rod or separation of the rocks adjacent to the bearing plate, because in such anchoring there is practically no anchor sliding. To prevent this, on the one hand, it is necessary to use high-quality materials such as high-strength steels and large-diameter rods, and on the other hand, to introduce flexible elements into the anchor structure. The problem is that the support system is too stiff and the support stresses in the mass are not developed.

In the coal industry of Great Britain, Australia and the United States, the construction and anchoring of workings with a rectangular cross-section is a common technology. In Germany, rock bolts are also widely used in the mining industry. For example, in the Augusta Victoria Mine, roof bolts were used in excavations with a rectangular cross-section (Figure 5).

Initially, the anchor was stressed with the force of 1300-1700 kN, then the force decreased to 1100-1400 kN. This measure was carried out in order to prevent future excessive stresses caused by rock deformations during arch stabilization.

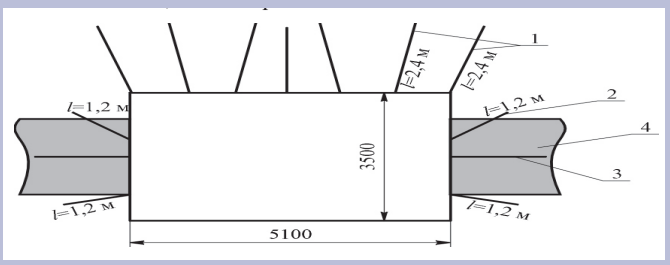

Figure 5. The diagram of the anchor arrangement:
1 – 2.4 m long anchors on the excavation roof; 2 – 1.2 m long anchors on the sides; 3 – 2.4 m long anchors in the coal seam; 4 – coal layer.

Сурет 5. Анкерлердің орналасу схемасы:
1 – қазба төбесіндегі ұзындығы 2,4 м анкерлер; 2 – бүйірлерінде ұзындығы 1,2 м анкерлер; 3 – көмір қабатындағы ұзындығы 2,4 м анкерлер; 4 – көмір қабаты.

Рис. 5. Схема расположения анкеров:
1 – анкеры длиной 2,4 м в кровле выработки; 2 – анкеры длиной 1,2 м в боках; 3 – анкеры длиной 2,4 м в угольном пласте; 4 – угольный пласт.

To ensure the ability to monitor the structure during operation, the control anchors in the wells along their entire length were not sealed with cement mortar. This made it possible to work with tension during operation.

The following anchor constructions are used in foreign and domestic practice: intermediate type metal anchors, reinforced concrete anchors, steel-polymer anchors with cores made of polymer materials, flexible anchors, movable anchors and rope anchors.

Three main types of intermediate anchors are used: wedge holes with an intermediate sleeve and two wedges. These anchors are always used pre-stressed. Intermediate anchors used in domestic practice have a number of significant disadvantages. Additional devices are required to attach these anchors to the well, which requires additional time and labor costs to mount them.

Conclusion

In the coal mines of the USA, Great Britain and the other countries, anchor rods with intermediate locks of various designs are common. In these anchors, the lock consists of two halves equipped with guides, between which a steel wedge is inserted and fastened to the threaded part of the anchor. Both are equipped with protrusions of different shapes on the outside, which are designed to eliminate vertical sliding during anchor operation and prevent rotation of the lock in the well when the anchor is attached. When mounting the anchor, both halves of the lock are held by a steel clamp, which temporarily fixes them with a wedge. A spiral spring serves to create a certain distance of the lock when mounting an anchor in a well, without using the mounting pipe for these purposes.

This article presents the results of scientific-applied research of production processes, the technology of conducting preparatory work in complex mining technical conditions of production of coal layers. The desire to secure anchor posts more reliably in weak rock has led to the development of foreign anchor post structures with extended locks or double locks to have a larger contact area between the anchor lock and the well walls. These anchors are very difficult and expensive to make, so they have not been widely used.

Acknowledgments

This research has been/was/is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR24992803).

REFERENCES

1. *Karenov R.S. Gorno-metallurgicheskaya otrasl' Kazakhstana: sovremennoe sostoyanie problem, strategicheskie prioritety razvitiya. / R.S. Karenov, Yu.D. Orynbasarova, Yu.B. Romanko T.B., Kazbekov. // Mezhdunarodnyi elektronnyi zhurnal matematicheskogo obrazovaniya. 2016. №11 (7). S. 2239-2254 [Karenov R.S. The mining and metallurgical industry of Kazakhstan: Current state of problems, and strategic development priorities. / R.S. Karenov, Y.D. Orynbassarova, Y.B. Romanko T.B. Kazbekov. // International Electronic Journal of Mathematics Education. 2016. №11 (7). P. 2239-2254] (in Russian)*
2. *Batyrkhanova A.T. Razrabotka tekhnologicheskikh skhem zabivnykh vyrabotok s upravlyaemym soprotivleniem konturov. / A.T. Batyrkhanova, A.N. Tomilov, A.Yu. Zhumabekova, U.E. Abekov. // Nauchnyi vestnik natsional'nogo gornogo universiteta. 2019. №3. S. 22-28 [Batyrkhanova A.T., Tomilov A.N., Zhumabekova A.Y., Abekov U.E. Developing technological schemes of driving workings with controlled resistance of contours. // Scientific Bulletin of the National Mining University. 2019. №3. P. 22-28] (in Russian)*
3. *Demin V.F. Otsenka effektivnosti tekhnologicheskikh skhem vyrabotok dlya povysheniya ustoichivosti ikh konturov. / V.F. Demin, T.V. Demina, A.S. Kainazarov, A.S. Kainazarova. // Ustoichivoe razvitie gornykh territorii. 2018. №10 (4). S. 606-616 [Demin V.F. Evaluation of the workings technological schemes effectiveness to increase the stability of their contours. / V.F. Demin, T.V. Demina, A.S. Kaynazarov, A.S. Kaynazarova. // Sustainable Development of Mountain Territories. 2018. №10 (4). P. 606-616] (in Russian)*
4. *Toderas M. Brief review of mining pressure and its manifestation regime in underground mining works. // Annals of the University of Petrosani Mining Engineering. 2022. №23. P. 13-30 (in English)*

5. *Kudryavtsev S.S. The development of a risk management system in the field of industrial safety in the Republic of Kazakhstan. / Kudryavtsev S.S., Yemelin P.V., Yemelina N.K. // Safety and Health at Work. 2018. №9 (1). P. 30-41 (in English)*
6. *Xie H. Experimental study on rock mechanical behavior retaining the in situ geological conditions at different depths. / Xie H., Li C., He Z., Li C., Lu Y., Zhang R., Gao F. // International Journal of Rock Mechanics and Mining Sciences. 2021. №38. P. 104548 (in English)*
7. *Sultanov M.G. Development of the choice of types of support parameters and technologies for their construction at the Voskhod field. / Sultanov M.G., Mataev A.K., Kaumetova D.S., Abdrashev R.M., Kuantay A.S., Orynbayev B.M. // Coal. 2020. №10. P. 17-21 (in English)*
8. *Nemova N.A. Technological solutions development for mining adjacent rock mass and pit reserves taking into account geomechanical assessment of the deposit. / Nemova N.A., Tahanov D., Hussan B., Zhumabekova A. // Scientific Bulletin of the National Mining University. 2020. №2. P. 17-24 (in English)*
9. *Moldagozhina M.K. The system is «roof bolting-mountain». / Moldagozhina M.K., Krupnik L., Koptileuovich Y.K., Mukhtar E., Roza A. // International Journal of Applied Engineering Research. 2016. №11 (21). P. 10454-10457 (in English)*
10. *Małkowski P. A comprehensive geomechanical method for the assessment of rockburst hazards in underground mining. / P. Małkowski, Z. Niedbalski. // International Journal of Mining Science and Technology. 2020. №30 (3). P. 345-355 (in English)*
11. *Zeitinova S. Numerical modeling the rock mass stress-strain state near vertical excavations in combined mining. / Zeitinova S., Imashev A., Bakhtybayev N., Matayev A., Mussin A., Yeskenova G. // Civil Engineering Journal. 2024. №10 (9). P. 2919-2934 (in English)*
12. *Demin V.F. Studying stress-strain state of border carbon massif around mine working with roof bolting. / Demin V.F., Portnov V.S., Demina T.V., Zhumabekova A.Ye. // Coal. 2019. №7. P. 72-77 (in English)*

ПАЙДАЛАНЫЛҒАН ӘДЕБИЕТТЕР ТІЗІМІ

1. *Каренов Р.С. Қазақстанның тау-кен металлургия өнеркәсібі: Проблемалардың қазіргі жай-күйі және дамудың стратегиялық басымдықтары. / Р.С. Каренов, Ж.Д. Орынбассарова, Ж.Б. Романко Т.Б. Қазбеков. // Математика білімінің халықаралық электрондық журналы. 2016. №11 (7). Б. 2239-2254 (орыс тілінде)*
2. *А.Т. Батырханова, А.Н. Томилов, А.Ж. Жумабекова, Ө.Е. Аббеков Контурлардың бақыланатын кедергісі бар жүргізу жұмысының технологиялық схемаларын әзірлеу. // Ұлттық тау-кен университетінің ғылыми хабаршысы. 2019. №3. Б. 22-28 (орыс тілінде)*
3. *Демин В.Ф. Контурлардың тұрақтылығын арттыру үшін технологиялық схемалардың жұмыс тиімділігін бағалау. / В.Ф. Демин, Т.В. Демина, А.С. Қайназаров, А.С. Қайназарова. // Таулы аумақтарды орнықты дамыту. 2018. №10 (4). Б. 606-616 (орыс тілінде)*
4. *Тодераш М. Тау-кен қысымына қысқаша шолу және жер асты тау-кен жұмыстарында оның көрініу режимі. // Петрозани тау-кен инжиниринг университетінің жылнамалары. 2022. №23. Б. 13-30 (ағылшын тілінде)*
5. *Кудрявцев С.С. Қазақстан Республикасында өнеркәсіптік қауіпсіздік саласындағы тәуекелдерді басқару жүйесін дамыту. / С.С. Кудрявцев, П.В. Емелин, Н.К. Емелина. // Еңбек қауіпсіздігі және еңбекті қорғау. 2018. №9 (1). Б. 30-41 (ағылшын тілінде)*
6. *Си Х. Әр түрлі тереңдіктегі ситукалық геологиялық жағдайларды сақтай отырып, тау жыныстарының механикалық мінез-құлқын эксперименттік зерттеу. / Х. Си, Ч. Ли, З. Хэ, Ч. Ли, Я. Лу, Р. Чжан, Ф. Гао. // Рок-механика және тау-кен ғылымдарының халықаралық журналы. 2021. №38. Б. 104548 (ағылшын тілінде)*
7. *Сұлтанов М.Ғ. Восход кен орнында тірек параметрлерінің түрлерін және оларды салу технологияларын таңдауды әзірлеу. / М.Ғ. Сұлтанов, А.Қ. Матаев, Д.С. Кауметова, Р.М. Абдрашев, А.С. Қуантай, Б.М. Орынбаев. // Көмір. 2020. №10. Б. 17-21 (ағылшын тілінде)*
8. *Немова Н.А. Кен орнының геомеханикалық бағасын ескере отырып, тау жынысы массасы мен шұңқыр қорларын өндіру бойынша технологиялық шешімдер әзірлеу. / Н.А. Немова, Д. Таханов, Б. Хусан, А. Жумабекова. // Ұлттық тау-кен университетінің ғылыми хабаршысы. 2020. №2. Б. 17-24 (ағылшын тілінде)*
9. *Молдағожина М.Қ. «Шатырлы болт-тау» жүйесі. / М.К. Молдағожина, Л. Крупник, Ж.К. Коптилеуович, Е. Мұхтар, А. Роза. // Қолданбалы инженерлік зерттеулердің халықаралық журналы. 2016. №11 (21). Б. 10454-10457 (ағылшын тілінде)*
10. *Мажковский П. Жер асты тау-кен қазбаларында тау жыныстарының қауіптіліктерін бағалаудың кешенді геомеханикалық әдісі. / Р. Мажковский, З. Нидбалски. // Тау-кен ғылымы мен технологиясының халықаралық журналы. 2020. №30 (3). Б. 345-355 (ағылшын тілінде)*

11. *Зейтинова С. Аралас тау-кен қазбаларында тік қазба жұмыстарының жанында жыныс массасының стресс-штамм жағдайын сандық модельдеу. / С. Зейтинова, А. Имашев, Н. Бақтыбаев, А. Матаев, А. Мусин, Г. Ескенова. // Азаматтық инженерия журналы. 2024. №10(9). Б. 2919-2934 (ағылшын тілінде)*
12. *Демин В.Ф. Шатырды бұрандамен жұмыс істейтін шахта айналасындағы шекаралық көміртекті массивтің стресс-штаммдық жай-күйін зерттеу. / В.Ф. Демин, В.С. Портнов, Т.В. Демина, А.Е. Жумабекова. // Уголь. 2019. №7. Б. 72-77 (ағылшын тілінде)*

СПИСОК ИСПОЛЬЗОВАННЫХ ИСТОЧНИКОВ

1. *Каренов Р.С. Горно-металлургическая отрасль Казахстана: современное состояние проблем, стратегические приоритеты развития. / Р.С. Каренов, Ю.Д. Орынбасарова, Ю.Б. Романко Т.Б., Казбеков. // Международный электронный журнал математического образования. 2016. №11 (7). С. 2239-2254 (на русском языке)*
2. *Батырханова А.Т. Разработка технологических схем забивных выработок с управляемым сопротивлением контуров. / А.Т. Батырханова, А.Н. Томилов, А.Ю. Жумабекова, У.Е. Абеков. // Научный вестник национального горного университета. 2019. №3. С. 22-28 (на русском языке)*
3. *Демин В.Ф. Оценка эффективности технологических схем выработок для повышения устойчивости их контуров. / В.Ф. Демин, Т.В. Демина, А.С. Кайназаров, А.С. Кайназарова. // Устойчивое развитие горных территорий. 2018. №10 (4). С. 606-616 (на русском языке)*
4. *Тодераш М. Краткий обзор горного давления и режима его проявления при подземных горных работах. // Летопись Университета горного дела Петросани. 2022. №23. С. 13-30 (на английском языке)*
5. *Кудрявцев С.С. Развитие системы управления рисками в области промышленной безопасности в Республике Казахстан. / С.С. Кудрявцев, В. Емелин, Н.К. Емелина. // Безопасность и гигиена труда. 2018. №9 (1). С. 30-41 (на английском языке)*
6. *Се Х. Экспериментальное исследование механического поведения горных пород при сохранении геологических условий в недрах на различных глубинах. / Х. Се, С. Ли, З. Хэ, С. Ли, Ю. Лу, Р. Чжан, Ф. Гао. // Международный журнал механики горных пород и горных наук. 2021. №38. С. 104548 (на английском языке)*
7. *Султанов М.Г. Разработка выбора типов параметров крепи и технологий их строительства на месторождении Восход. / М.Г. Султанов, А.К. Матаев, Д.С. Кауметова, Р.М. Абдрашев, А.С. Куантай, Б.М. Орынбаев // Уголь. 2020. №10. С. 17-21 (на английском языке)*
8. *Немова Н.А. Разработка технологических решений по отработке прилегающей горной массы и карьерных запасов с учетом геомеханической оценки месторождения. / Н.А. Немова, Д. Таханов, Б. Хусан, А. Жумабекова. // Научный вестник национального горного университета. 2020. №2. С. 17-24 (на английском языке)*
9. *Молдагожина М.К. Система представляет собой «кровельное крепление-гора». / М.К. Молдагожина, Л. Крупник, Ю.К. Коптилеуович, Е. Мухтар, А. Роза. // Международный журнал прикладных инженерных исследований. 2016. №11 (21). С. 10454-10457 (на английском языке)*
10. *Малковский С. Комплексный геомеханический метод оценки опасности горных взрывов при подземных горных работах. / С. Малковский, З. Недбальский. // Международный журнал горной науки и техники. 2020. №30 (3). С. 345-355 (на английском языке)*
11. *Зейтинова С. Численное моделирование напряженно-деформированного состояния массива горных пород вблизи вертикальных выработок в комбинированных горных работах. / С. Зейтинова, А. Имашев, Н. Бахтыбаев, А. Матаев, А. Мусин, Г. Ескенова. // Журнал гражданского строительства. 2024. №10 (9). С. 2919-2934 (на английском языке)*
12. *Демин В.Ф. Изучение напряженно-деформированного состояния граничного углеродного массива вокруг шахтной работы с анкерной крепью. / В.Ф. Демин, В.С. Портнов, Т.В. Демина, А.Е. Жумабекова. // Уголь. 2019. №7. С. 72-77 (на английском языке)*

Information about the authors:

Zhumabekova A.Ye., Ph.D, acting docent of the Department «Development of Mineral Deposits», NJSC «Abylkas Saginov Karaganda Technical University» (Karaganda, Kazakhstan), *aila1980@mail.ru;* https://orcid.org/0000-0002-1501-5382

Khalikova E.R., acting docent of the Department «Development of Mineral Deposits», NJSC «Abylkas Saginov Karaganda Technical University» (Karaganda, Kazakhstan), *salyahova_e@mail.ru;* https://orcid.org/0000-0003-1501-8492

Meiram D.D., Ph.D doctoral student of the department «Development of mineral deposits» NJSC «Abylkas Saginov Karaganda Technical University» (Karaganda, Kazakhstan), *diana_mairam@mail.ru;* https://orcid.org/0009-0003-6092-4790

Syzdykbayeva D.S., Ph.D student of the department «Development of mineral deposits» NJSC «Abylkas Saginov Karaganda Technical University» (Karaganda, Kazakhstan), *dikow-1290@mail.ru;* https://orcid.org/0000-0002-0673-0384

Авторлар туралы мәліметтер:
Жумабекова А.Е., «Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КЕАҚ «Пайдалы кенорындарын қазып өнді ру» кафедрасының доцент м.а. (Қарағанды қ., Қазақстан)
Халикова Э.Р., «Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КЕАҚ «Пайдалы кенорындарын қазып өнді ру» кафедрасының доцент м.а. (Қарағанды қ., Қазақстан)
Мейрам Д.Д., «Абылқас Сағынов атындағы Қарағанды техникалық университеті» АҚ «Пайдалы қазбалар кен орындарын игеру» кафедрасының Ph.D студенті (Қарағанды қ., Қазақстан)
Сыздыкбаева Д.С., «Абылқас Сағынов атындағы Қарағанды техникалық университеті» АҚ «Пайдалы қазбалар кен орындарын игеру» кафедрасының Ph.D докторанты (Қарағанды қ., Қазақстан)

Сведения об авторах:
Жумабекова А.Е., и.о. доцента кафедры «Разработка месторождений полезных ископаемых», НАО «Карагандинский технический университет имени Абылкаса Сагинова» (г. Караганда, Казахстан)
Халикова Э.Р., и.о. доцента кафедры «Разработка месторождений полезных ископаемых», НАО «Карагандинский технический университет имени Абылкаса Сагинова» (г. Караганда, Казахстан)
Мейрам Д.Д., докторант кафедры «Разработка месторождений полезных ископаемых» НАО «Карагандинский технический университет имени Абылкаса Сагинова» (г. Караганда, Казахстан)
Сыздыкбаева Д.С., докторант кафедры «Разработка месторождений полезных ископаемых» НАО «Карагандинский технический университет имени Абылкаса Сагинова» (г. Караганда, Казахстан)