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Satbayev University

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РЕСПУБЛИКИ КАЗАХСТАН
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USE OF MINING AND METALLURGICAL WASTE AS A BACKFILL OF WORKED-OUT SPACES

Abstract. The sustainable growth of the economic development of the mining industry directly depends on the level of implementation of innovative technologies in production. Rational use of subsoil in the development of deposits should be based on the maximum completeness and complexity of extraction of useful components. Today, the issue of introducing low-waste and non-waste environmentally friendly technologies is especially acute. The main direction of using waste from mining and metallurgical production is the filling of mined spaces. There is extensive experience in the use of production wastes in stowing operations, technologies for stowing operations have been developed, which are used in many mines at the mines of East Kazakhstan. One of the urgent tasks in these conditions is the development of resource-saving technologies for the extraction of minerals based on the diversification of the products of mining enterprises, which ultimately will reduce the cost of mining and increase the profitability of production and the competitiveness of the final products of mining companies.

The article provides a substantiation of the main direction of using mining and metallurgical waste as a backfill of mined spaces, a resource-saving technology of mining based on the diversification of the output of mining enterprises, parameters of reducing the cost of mining and increasing the profitability of production and the competitiveness of the final products of mining companies and parameters of reliable artificial massifs in mining systems with backfilling of mined spaces are given [1]. It is recommended to use the technology at mining enterprises with complex mining and geological conditions.

Key words: underground method, filling operations, safety factor, mining, mixture.

Introduction. Backfill mining systems have been widely used in mining of ore deposits, both at foreign and domestic mines in recent years [2]. In particular, there is extensive experience in the use of production wastes in stowing operations at the mines of East Kazakhstan, technologies for stowing operations have been developed for various mining and geological conditions, which are used at Maleevsky, Tishinsky, Artemyevsky, Orlovsky and other mines.

Nowadays, the technologies used for ore mining by the underground method do not provide for the complete disposal of production wastes in the mined area. This primarily applies to the disposal of man-made raw materials containing toxic waste such as arsenic. Refractory gold - arsenic ores in our country are practically not processed due to the lack of rational and environmentally friendly technology. An important problem in the technology of complex processing of semi - finished products of metallurgical production is the removal, neutralization, and disposal. Therefore, the development of compositions of hardening filling mixtures with the use of arsenic - containing mining waste is very important and relevant.

Materials and methods. Research methods are defined based on research standards. Experiments are envisaged for carrying out technological tests, which are also limited by the available equipment and expert staff [3]. The study used an industrial experiment at a mining enterprise.

The development of a new type of reinforcement for artificial roofing in mines is based on the principles of barbelling a layered artificial massif experiencing forces from its own weight of roofing layer and retaining its detached elements with a rigid metal mesh. Wherein, the problem of improving the safety of mining operations is solved by picking up the entire area of the exposed filling massif, eliminating the fallout of its detached and cracked pieces.

Results and discussion. Experimental results on the reliability of the filling massif for the downward mining of ore layers. It should be noted that mining of valuable ore deposits is carried out in descending layers, when equipment and personnel work in a chamber with an artificial massif top. It is clear that the reliability of the top (backfill) must be high. According to the statistics of the Bakyrchik gold mine operation, the reliability $P_з$ of the artificial top as a function of the safety factor $К_з$ of its strength will be investigated by us in the interval:

$$\left.\begin{aligned} 0{,}9 \le P_з \le 0{,}99 \\ 2 \le К_з \le 14 \end{aligned}\right\} \qquad (1)$$

which is enough for practical purposes.

The categories of stability of the filling massif in the bearing layer were determined (Table 1) and recommendations on the method of maintaining an artificial top were developed (Table 2) based on these studies.

Table 1- Stability category of filling mass

Massif stability category	Height of base layer $h_н$	Safety factor, $К_з$	Stability of artificial massif, MPa	
			with reinforcement	Without reinforcement
I (stable)	1.2 1.5	5	More than 4.5 More than 4.0	более 3.5 более 3.0
II (average stability)	1.2 1.5	from 2,5 to 5	from 4.5 to 3.0 from 4.0 to 3.0	от 3.5 до 2.5 от 3.0 до 2.0
III (unstable)	1.2 1.5	Less than 2,5	Less than 3.5 Less than 3.0	Less than 2.5 Less than 2.0

Table 2 – Method of maintaining an artificial top, depending on the stability

Stability category	Method of maintaining an artificial top
I category (stable)	Without binding
II category (average stability)	Without binding, with the organization of monitoring the condition of the top by signal racks
III category (unstable)	Wooden frame or metal support with a step of 2 m with a top tightening with a lag from the bottom of the face no more than 4 m

For the adopted mining system and parameters of the clearing, the standard strength, in accordance with the calculations, should be:

- 4 - 4.5 MPa in the carrier layer with height 1.5 m;
- 1 - 1.5 MPa above carrier layer – refilling.

The main processes of the technology for the construction of artificial massifs are:

- preparation of the mined space for filling;
- reinforcement and isolation of the mined space;
- construction of an artificial massif, providing the normative strength and support of the overlying massif.

Water is removed and a concrete pipeline is brought after the extraction of ore in the stope. A layer of ore fines with a thickness of 0.10 - 0.2 m is left on the bedrock of the entry to exclude the harmful effect of explosions on the filling mass.

The development of a new type of artificial top reinforcement at the Bakyrchik mine is based on the principles of barbell a layered artificial massif experiencing forces from its own weight of the immediate top layer and retaining its exfoliated elements with a rigid metal mesh. At the same time, the task of increasing the safety of mining operations is being solved by taking up the entire area of the exposed filling massif, eliminating the loss of its exfoliated and cracked pieces [1 - 3].

In the block being mined, a mine is prepared with parameters (height x width) - 3.5 x 4 m. A metal mesh is laid on the bedrock of the mine, on the bedding of ore fines with a height of 100 mm and above this ore fines at a height of about 50 mm, a metal mesh is laid, with cell parameters of 100 x 100 mm. The metal mesh is a rigidly welded structure laid across the roadway in strips of 4000 x 1200 mm. An iron wire with a diameter of 6 mm is fixed along the roadway at a height of 2800 mm. A demonstration of such reinforcement is shown in Figure 1.

An insulating bulkhead is installed before laying the entry in the outfall. If the length of the entry is more than 25 m, intermediate technological jumpers with a height of at least two meters should be installed, which prevent the mixture from stratifying when spreading at an angle of 3 - 5°. The insertions are made in such a way that the height of the hardening mixture, supplied at one time, is at least 1.5 m. The remaining part of the mined space is filled after the hardening mixture has set in the carrier layer. The break between the first and second doses should be at least 15 - 20 hours.

a)  b) 

a) the type of reinforcement on the bedrock of the layer before laying; b) the type of reinforcement after laying the bearing layer.

1 – mining working; 2 – vertical rod; 3 - rigid metal mesh; 4 - pickup, 5 - horizontal support

Figure 1 – Formation of an artificial massif with a vertical rod reinforcement and a rigid metal mesh near the bedrock.

The filling pipeline is cleaned by blowing it with compressed air with a small amount (0.5-1.0 m^3) of water after the end of the supply of the hardening mixture.

Most attention is paid to the selection of the optimal composition of the filling mixtures with the ratio of tailings - crushed rock (50:50 by volume) and with or without the presence of more than 2.5 mm class in the coarse aggregate. The weight ratios of the compositions are shown in Table 3.

The following conclusions can be drawn as a result of the work: the method for determining the mobility of a mixture by the draft of a standard cone requires improvement and for filling mixtures does not reflect the actual value of mobility.

The reliability of the pipeline depends on the correct choice of the speed mode of transportation. When transporting dynamically stable mixtures, which include polydisperse filling mixtures, the working speed of movement must be at least 10 - 15% higher than the critical one. The critical speed is considered to be such that the larger, heavier particles in the mixture can precipitate. As a result, blockage of the pipeline can occur.

Investigation of the rheological properties of filling mixtures and the strength properties of artificial massifs [4, 6]. Determination of the delamination of the mixture, i.e. the property to lose homogeneity during transportation and laying was carried out in a special device. It consists of two rings and a cylinder with a bottom, assembled on rubber gaskets and tightened with rods [7, 8].

It was determined in laboratory conditions that the spreadability of the mixture largely depends on the ratio of solid to liquid and on the presence of a fine class (- 0.074 mm), in the presence of a fine class of less than 20%, the mixture immediately stratified (Kp ≥ 1.3).

Table 3 - Backfill composition

№ composition	Consumption of materials for 1 $м^3$, kg					
	Cement	Tailings γ	Tailings γ	Crushed rock – 2.5 mm	Crushed rock + 2.5 mm	Water
I	250	566	-	566	-	500
II	250	566	-	428	138	500
III	250	-	879	593	-	480
IV	250	-	879	424	172	480

Different aggregates can significantly differ in the specific surface of the grains with the same modulus of grain size and average grain diameters, which is important for assessing the water demand and mobility of the mixture [9 - 11]. Therefore, we evaluated the aggregates by the surface modulus, which expresses the surface of the particles in m² per 1 liter of absolute volume. The surface modulus is determined by the formula:

$$M_п = 16,5 \times К \times (a + 2\,b + 4\,c + 8\,g + 16\,d + 36\,e) / 1000, \qquad (2)$$

where a, b, c, g, d – remains on screen with hole sizes 2.5; 1.25; 0.63; 0.315; 0.14 mm;

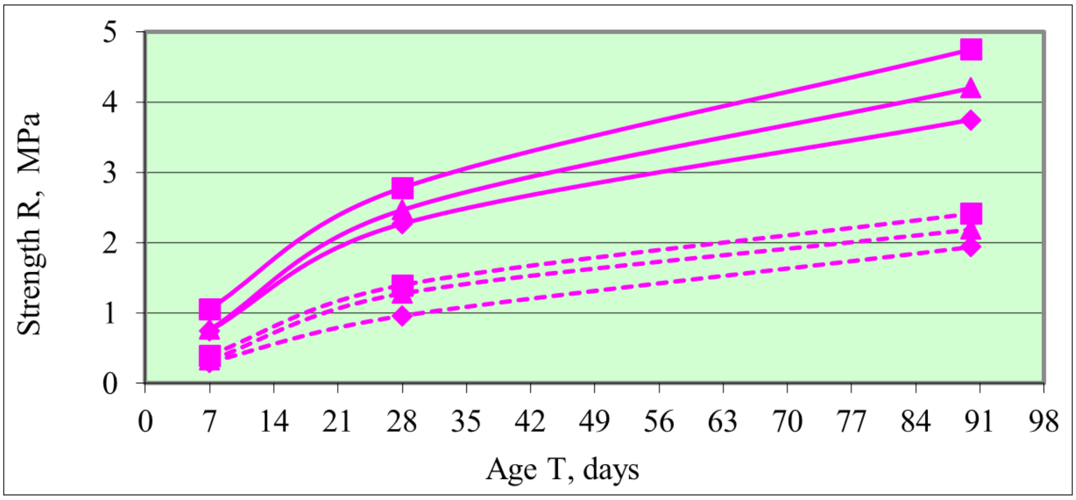
e – fraction number – 0.14 mm, %;

К – the aspect ratio, which expresses the ratio of the surface of the grains of the aggregate to the surface of the spherical particles, is taken equal to 2.1 for crushed and ground particles.

The ultimate shear stress was determined using a Sternbeck device. A steel cylinder with a height of 0.15 m and a diameter of 0.2 m was filled with the test mixture and placed on a flat support. The cylinder was connected with a rigid thread thrown over a pulley with a measuring vessel, the mass of which is equal to the mass of the cylinder. Water is poured from the tank into a measuring vessel until the moment the cylinder begins to shift relative to the mixture.

The angle of spreading of the hardening mixture without special additives in the poured space depends on the ratio of solid to liquid (at least 3.5 to 1) and with a granulometric composition that ensures its pipeline transport: large class (+ 2.5 mm) – 10 ÷ 15%; middle class (- 2.5 ÷ + 0.074 mm) – 55 ÷ 65%; small class (-0.074 mm) - 30÷35%, is 1 - 2 degrees.

It has been established that the compositions of filling mixtures based on stale tailings at 90 days of age have specimen strength by 10-15% more than current tailings. At the same time, grinding crushed rock gives a 10% increase in strength (Figure 2), which confirms the effectiveness of the mill method for preparing backfill mixtures.



■ - laying tailings: screening: grinded rock;

▲ - current tailings: screening: grinded rock;

♦ - current tailings: screening: crushed rock.

Figure 2 - Dependence of the strength of cube specimens on the composition of the filler (cement consumption: 1 – 250 kg/ m³; 2 – 150 kg/ m³).

Conclusion. The reliability of the design of mining systems with a hardening backfill is determined by the intersection of random values of loads on the ceiling and sides of the chambers, as well as on massive artificial pillars with deterministic boundaries of the strength of the backfill for compression and tension, and at the same time is described by complex nonlinear functions of the physical and mechanical properties of the rock mass, filling massif and technological parameters of mining systems of ore bodies. The results of scientific research were introduced at the Bakyrchik mine (Kazakhstan), and they passed industrial tests. Thus, the laboratory studies performed have shown the technical feasibility of obtaining hardening filling mixtures using stale and flowing tailings as a filler with a wide range of rheological and strength properties, depending on the ratio of the constituent components. The mill method of preparation makes it possible to obtain a filling mixture that is uniform and homogeneous in composition, which is not prone to delamination.

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ТАУ-КЕН МЕТАЛЛУРГИЯ ӨНДІРІСІНІҢ ҚАЛДЫҚТАРЫН ҚАЗЫЛҒАН КЕҢІСТІКТЕРДІ БІТЕУ НЕГІЗІНДЕ ПАЙДАЛАНУ

Аннотация. Тау-кен өндіру саласының экономикалық дамуының тұрақты өсуі өндіріске инновациялық технологияларды енгізу деңгейіне тікелей байланысты. Кен орындарын игеру кезінде жер қойнауын ұтымды пайдалану пайдалы компоненттерді алудың барынша толықтығы мен кешенділігіне негізделуі тиіс. Бүгінде аз қалдықты және қалдықсыз экологиялық таза технологияларды енгізу мәселесі өте өзекті. Тау-кен металлургия өндірісінің қалдықтарын пайдаланудың негізгі бағыты – өңделген кеңістікті төсеп толтыру. Шығыс Қазақстанның кеніштерінде өндірістік қалдықтарды қалау жұмыстарында қолданудан үлкен тәжірибе жинақталып, көптеген кеніштерде қолданылатын өңдеу жұмыстарының технологиялары жасалды. Бұл өзекті міндеттердің бірі болып тау-кен кәсіпорындарының өнімін әртараптандыруға негізделген пайдалы қазбаларды өндірудің ресурс үнемдеу технологиясын әзірлеу, түптеп келгенде, пайдалы қазбаларды өндірудің құнын төмендетуге, сонымен қатар өндірістің рентабельділігі мен бәсекеге қабілеттілігін арттыруға мүмкіндік береді.

Мақалада тау-кен металлургия өндірісінің қалдықтарын өндірілген кеңістікті толтыруға пайдаланудың негізгі бағыты, тау-кен кәсіпорындары шығаратын өнімдерді әртараптандыруға негізделген тау-кен өндірісінің ресурс үнемдейтін технологиясы, сонымен қатар пайдалы қазбаларды өндіру құнын төмендету параметрлері келтірілген және өндіріс рентабельділігі мен өндіруші кәсіпорындардың соңғы өнімдерінің бәсекеге қабілеттілігін жоғарылату, өндірілген кеңістікті қайта толтырумен өңдеу жүйелеріндегі сенімді жасанды тау-кен жыныстары массасының параметрлері келтірілген. Аталған технологияны күрделі тау-геологиялық жағдайдағы кәсіпорындарда қолдану ұсынылады.

Түйінді сөздер: жер асты тәсілі, төсеу жұмыстары, беріктік қорының коэффициенті, кен орындарын өңдеу, қоспа.

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ИСПОЛЬЗОВАНИЯ ОТХОДОВ ГОРНО-МЕТАЛЛУРГИЧЕСКОГО ПРОИЗВОДСТВА КАК ЗАКЛАДКИ ВЫРАБОТАННЫХ ПРОСТРАНСТВ

Аннотация. Стабильный рост экономического развития горнодобывающей отрасли напрямую зависит от уровня внедрения в производство инновационных технологий. Рациональное использование недр при разработке месторождений должно основываться на максимальной полноте и комплексности извлечения полезных ископаемых. На сегодняшний день особенно остро стоит вопрос внедрения малоотходных и безотходных экологически чистых технологий. Основное направление использования отходов горно-металлургического производства, это закладка выработанных пространств. На рудниках Восточного Казахстана имеется большой опыт применения отходов производства на закладочных работах, разработаны технологии ведения закладочных работ, которые применяются на многих рудниках. В этих условиях одной из актуальных задач является разработка ресурсосберегающих технологий добычи полезных ископаемых на основе диверсификации выпускаемой продукции горнодобывающих предприятий, что в конечном итоге позволит снизить себестоимость добычи полезных ископаемых, а также повысить прибыльность производства и конкурентоспособность конечной продукции горнорудных предприятий.

В статье дано обоснование основного направления использования отходов горнометаллургического производства как закладки выработанных пространств, приведена ресурсосберегающая технология добычи полезных ископаемых на основе диверсификации выпускаемой продукции горнодобывающих предприятий, приведены параметры снижения себестоимости добычи полезных ископаемых и повышения прибыльности производства и конкурентоспособности конечной продукции горнорудных предприятий, приведены параметры надежных искусственных массивов при системах разработки с закладкой выработанных пространств и рекомендовано использование технологии на горных предприятиях со сложными горно-геологическими условиями.

Ключевые слова: подземный способ, закладочные работы, коэффициента запаса прочности, отработка залежей, смесь.

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