MODERN APPROACH TO THE TECHNOLOGY OF THE BACKFILLING

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ABSTRACT. The article describes a modern approach to the technology of backfilling of working space, taking into account the sustainable development of mining. The aspects of economic efficiency, safety and ecology are considered. A detailed analysis of various backfilling methods that are used in modern enterprises is given. The advantages and disadvantages are given. The article describes in detail the work carried out in this area at the Mining Institute of NUST "MISiS". One of the directions is the study of the possibility of using local natural materials or waste products as backfills. In particular, studies were carried out on the formation of backfill arrays based on sulphide-containing and halite tailings. The influence of the granulometric composition and ratio of coarse and fine aggregateson the quality of the backfill, as well as their quantity per unit of volume, amount of water (water binding ratio), method of preparation, transportation and styling, conditions (temperature) and age of hardening are also considered.

Keywords: sustainable mining, backfilling, industrial waste, ecology

МОДЕРЕН ПОДХОД КЪМ ТЕХНОЛОГИЯТА НА ЗАПЪЛВАНЕ

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РЕЗЮМЕ. Статията описва модерен подход към технологията на запълване на отработеното пространство, като се отчита устойчивото развитие на минните работи. Разгледани са аспектите на икономическата ефективност, безопасността и екологията. Даден е подробен анализ на различните методи за запълване, които се използват в съвременните предприятия. Представени са предимствата и недостатъците. Статията описва подробно работата, извършена в тази област в Минния институт на НУНТ "МИСиС". Едно от направленията е проучването на възможността за използване на местни естествени материали или отпадни продукти за запълването. По-специално бяха проведени проучвания за формирането на запълващи масиви на базата на сулфидни и халитовиотпадъци. Разгледани са също влиянието на гранулометричния състав и съотношението на груби и фини инертни материали върху качеството на запълване, както и тяхното количество спрямо единица обем, количеството вода (съотношение на свързването с вода), метод на приготвяне, транспортиране и стилизиране, условия (температура) и възраст на втвърдяване.

Ключови думи: устойчиво развитие, минни работи, запълване, технологични отпадъци, екология

Introduction

Man-made disasters during the extraction of minerals occur more frequently. In 2007 there was acollapse of the surface at BKRP-1 Uralkali, in2014 - water breakthrough at the "Solikamsk-2"mine, in 2017 - a breakthrough of water from a spent pit to an underground mine at the Mir enterprise in Yakutia, etc. (Khayrutdinov, 2007; Khayrutdinov, Ivannikov, 2017).This demonstrates the need for a more thorough development of technology at the mine design stage.

One of the ways to minimise man-made disasters is the use of technology with backfilling of working space (Khayrutdinov, 2009).

An analysis of global experience shows that up to 35% of mines use development systems with backfilling. This is due to the deepening of the mines and the complication of mining and geological conditions. Especially in an environment of constant struggle for the minerals extraction completeness. Due to the high value of the extracted raw materials, underground mines mainly use systems with hardening backfilling based on the cement binder component (Khayrutdinov, 2009; Khayrutdinov, Ivannikov, 2017). And in coal mines dry or hydraulic backfilling isused. At the same time, coarse-ground rocks from sinking, finely crushed coal waste ore,specially mined sand are used. Hardening backfilling in coal mines is used only in exceptional cases: when extracting powerful, steeply dipping layersor reducing endogenous fire hazard or when mining layers under guard objects (Khayrutdinov, Shaymyardyanov, 2009; Khayrutdinov, 2008).

The use of backfilling of working space allows the control of mining pressure and increasing the safety of mining operations as well as simultaneous mining of the deposit by underground and open methods. This increases the recovery rate, and also reduces the negative impact of mining on the environment (Khayrutdinov, 2008). In addition, the use of backfilling in the extraction of minerals allows to the extraction of reserves, previously considered off-balance or left in the pillars. This, in addition to reducing losses and improving the quality of extraction, leads to an increase in the lifetime of the mine that in turn allows to solve the social issue in the regions where the mining enterprise is a city-forming one (Khayrutdinov, Ivannikov, 2017).

Despite the advantages of underground geotechnology with backfilling of working space, at the same time it increases the cost of mining. And therefore, requires the improvement of the relevant processes.

In most cases, the mines "Severny" (Murmansk region), "International" (Yakutia), "Geko" (Canada) and some others use a specially mined aggregate for filling the mines. It is characterised by inconstancy of particle size distribution, humidity, material composition, etc. Therefore, it is associated with relatively high costs (Khayrutdinov, 2008).

Adding to the filling mixture an excessive amount of water in order to increase its transportability leads to the separation of the mixture during transportation. And, as a result, to reduce the strength of the backfill array. For example, at the Outokumpu mine (Finland), with the transition of refining operations to deeper horizons, the side walls of artificial pillars collapsed. In order to eliminate the negative effects of excess water in mixtures, the consumption of the binder was increased that led to an increase in mining costs (Khayrutdinov, Ivannikov, Arad, Huang, 2017).In addition, it should be borne in mind that the use of backfill in mining operations is associated with the construction of backfill complexes. They require significant financial costs as well as complicated technological scheme of the process of mining (Khayrutdinov, 2007; Khayrutdinov, Shaymyardyanov, 2009).

As can be seen, the use of technologies with backfilling is associated with significant costs and is effective in developing more valuable ores.

The use of local natural materials and waste products will significantly reduce the costs not only for backfilling, but also for the maintenance of various types of dumps and tailings. Accordingly, land areas for mining allotments are reduced (Khayrutdinov, 2007; 2009; Khayrutdinov, Votyakov, 2007a; 2007b; Khayrutdinov, Ivannikov, 2017).

The rational use of elements of backfilling with disposal in laying the waste of mining and processing production will allow to effectively develop less valuable mineral deposits.

As it was mentioned above, the use of waste not only affects the technical and economic indicators of the mining enterprise, but also helps to reduce the harmful environmental impact on the environment (Yushina et al., 2019).

The application of the technology of hardening backfill with the utilisation of waste from mining and processing production will significantly reduce the cost of the process and will allow the effective development of mineral deposits (Khayrutdinov, 2007; Khayrutdinov, Ivannikov, 2017).

Work on laying concrete mixes in underground workings was carried out by our scientists before (Kulikova, 1994).But, since 2000 research work has been carried out at the Moscow State Mining University for evaluating the possibility of using mining waste for laying the mined-out space in underground mining of ore deposits. Studies on the formation of backfill arrays on the basis of sulphide-containing and halite tailings of enrichment showed that, if there are appropriate activation methods, they can be successfully used as aggregate. Analysis of the data obtained shows that there are no tailings that could not be used in the tab as inert aggregate and some can be used as a binder component (Khayrutdinov, Votyakov, 2007a; 2007b; Khayrutdinov, Votyakov, 2007).

If spent mines are not intended to be used in any other capacity, for example, for gas storage(Myaskov, Popov, Popov, Gornyi Zhurnal, 2018), then the use of technology development enterprises with a backfilling on the basis of waste mining production allows to expand the raw material base for the preparation of hardening bookmarks,to free up part of the territory for its more efficient use for sowing or building structures, to reduce the negative impact of tailings and waste dumps on adjacent areas, as well as to reduce irrational transportation, reduce loading and unloading operations and free up part of the rolling stock for the transport of other goods (Khayrutdinov, 2007; 2009; Khayrutdinov, Shaymyardyanov, 2009; Khayrutdinov, Ivannikov, 2017).

Thus, research on the use of mining waste, including those with restrictions, is not only promising, but also solves a number of economic and environmental problems.

The backfill array is characterised by a rather long setting time (curing). This results in poor performance. In the same time the use of various additives that regulate the setting time increases the filling rate that sometimes leads to cases of solidification of the solution in the pipelines (Khayrutdinov, Votyakov, 2007; Khayrutdinov, Ivannikov, Arad, Huang, 2017).

The use of dry or hydraulic backfilling when mining secondary chambers leads to the penetration of backfill material into the ore and, accordingly, to an increase in ore dilution.

Artificial backfill array is a foreign body inside the mountain range. Its quality is determined by several indicators: strength, compression, rheological properties, as well as stability in the outcrop. It is very important to ensure those properties of the backfilling that are acceptable for specific mining conditions (Khayrutdinov, Votyakov, 2007a; 2007b; Khayrutdinov et al., 2017).

The properties of a hardening backfill array are most significantly influenced by: quality, particle size distribution, and the ratio of coarse and fine aggregates as well as their number per unit volume, amount of water (water binding ratio), method of preparation, transportation and installation and also the conditions (temperature) and the age of hardening (Khayrutdinov, Votyakov, 2007).

Studies show that one of the determining factors for the efficiency of a mixture is its water content. The technology of backfilling at the mining enterprises is characterised by the presence of a significant amount of water in mixtures (up to 550 kg/m3). This dramatically reduces the strength of the artificial array and impairs the technical and economic indicators of the use of development systems with a backfilling (Khayrutdinov, Votyakov, 2007).

The increase in the mass fraction of the solid constituent in the mixture is a significant reserve for reducing the consumption of the binder.

The type and ratio of aggregates also affect the strength of the filling mixture. The filler in the mixture is 70-90% (mass.). It is significantly cheaper knitting. Therefore, it is economically advantageous that the filling mixture contains as much aggregate as possible and as little binder as possible. However, economic considerations are not the only ones when choosing a placeholder. For the stability of the artificial array the grain composition of the aggregateis also important. It affects the moistening of the surface of the grains, the relative volume of the aggregate, the good stowability of the filling mixture, and its tendency to delamination (Khayrutdinov, Votyakov, 2007).

An important characteristic of the backfilling is the dynamics of strength in time. The pattern of growth of strength is important in determining the minimum time to start working out of the pillars. This affects the choice of parameters for development systems. Studies have shown that the most intense increase in strength is observed during the first 60 days of hardening. In the subsequent period (up to 3 months), the increase in strength slows down somewhat (an increase of 10-17%). Over the next 3 months there is an even slower increase in strength (by 3-5%). And over the next six months, it increases by another 2-3% (Khayrutdinov, Votyakov, 2007).

Characteristics of the future backfill array largely depend on the properties of the source materials. Therefore, their correct choice is one of the most important factors in the backfill technology. The setting time of the filling mass should not be less than the required time for delivery of the mixture to the space developed. This is especially important for mixtures with coarse aggregate. As in this case, the stratification leads to an uneven distribution of the constituent components in the developed space and also to the heterogeneity of the artificial array and reduced strength. The composition of the filling mixture should be such that high temperatures do not develop in the artificial massif, which have a detrimental effect on its solidity. Theshrinkage of the mixture would be minimal (Khayrutdinov, Votyakov, 2007; Khayrutdinov et al., 2017).

A series of experiments allowed to determine the influence of the content of magnesia cement in the backfill on its strength. For comparison, samples of hydraulic backfill were simultaneously produced.

Halite waste and magnesia cement, taken in the required amount relative to each other, were mixed for 3 minutes. The mixture obtained was sealed with a saturated solution of halite waste with a density of 1.35 g/cm^3 at a temperature of 25°C in an amount that provides the mobility of the mixture along the Suttard taper of 20 cm. The resulting mixture was mixed for 2 minutes until a homogeneous mass was obtained. The results of testing the strength of the uniaxial compression are given in Table 1 and Figure 1.

Table 1. *Mixture wastes based on enrichment waste with different binder content*

Composition number	The content of components, wt.%		The ratio of saturated solution to solid	Sample Strength under uniaxial compression, MPa			
	Waste	Magnesia cement		Duration of curing, day			
				7	28	60	90
1	99.5	0.5	0.15	-	0.3	0.7	0.8
2	99	1	0.15	0.05	0.65	1	1.25
3	97.5	2.5	0.15	0.10	0.9	1.65	1.8
4	95	5	0.15	0.25	1.7	2.6	2.8
5	100	-	0.15	-	0.1	0.25	0.3

The graph in Fig. 1 shows that the strength of the studied samples increases substantially in proportion to the content of magnesia cement in the filling mixture.

When choosing a technology for extracting minerals from the depths, it is necessary to take into account a combination of many factors: economic, environmental and safety. The use of technology with the backfilling of working space on the basis of man-made waste, allows for more efficient use of natural resources.

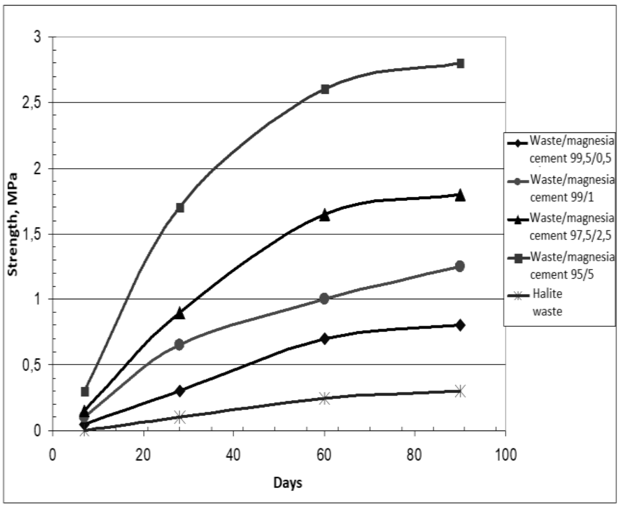

Fig. 1. The kinetics of backfilling strength with differentbinder content

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