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SOME ASPECTS OF IMPROVING UNDERGROUND MINING DEPOSITS OF COMPLEX STRUCTURE WITH A CONCRETE FILLING

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Abstract: The article details the concept of improving the underground mining of complex structure metal deposits by using systems filling mined-out spaces with solid mixtures. The purpose of the study is to generalize the experience of intensive ore mining while preserving the earth's surface, as an indicator of the environmentally correct development technology. The research methodology includes observation in full-scale and laboratory conditions, comparison with analogues, experiment, analysis of results, engineering forecasting, semi-industrial and industrial implementation, and theoretical experimentation using standard and new methods. The results of the study. The study highlights the correlation between the performance of ore-bearing stress-deformed rocks, stability of natural and artificial massifs and mine workings. It was determined that structural heterogeneities account for the discrepancy between stresses in massifs and the geostatic distribution law and a mathematical-analytical model for consolidation of discrete rocks was used in the studies. The article shows that voltage regulation makes it possible to use less expensive technologies to reclaim the mined –out space. The study assesses the possibility of using mill tailings, heap leaching, hydrometallurgy, mine waters, ash from electrofilters and wastewater from CHP plants as part of hardening mixtures. The research also considers the issues of environmental safety. The results of the study can be used in modernization of the existing and design of a new mining production.

Keywords: complex-structure deposit, underground mining, hardening mixture, environment

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К КОНЦЕПЦИИ СОВЕРШЕНСТВОВАНИЯ ПОДЗЕМНОЙ РАЗРАБОТКИ МЕСТОРОЖДЕНИЙ СЛОЖНОЙ СТРУКТУРЫ С БЕТОННОЙ ЗАКЛАДКОЙ

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Аннотация: Статья детализирует концепцию совершенствования подземной разработки металлических месторождений сложной структуры системами с закладкой выработанного пространства твердеющими смесями. Целью исследования является обобщение опыта интенсивной добычи руд с сохранением земной поверхности, как гаранта экологической корректности технологии разработки. Методика исследования включает в себя наблюдение в натурных и лабораторных условиях, сравнение с аналогами, эксперимент, анализ результатов, инженерное прогнозирование, полупромышленное и промышленное внедрение, и теоретическое экспериментирование по стандартным и новым методикам. Результаты исследования. Установлены особенности корреляции поведения рудовмещающих напряженно-деформированных пород, устойчивости природных и искусственных массивов и горных выработок. Определено, что не соответствие напряжений в массивах геостатическому закону распределения объясняются наличием структурных неоднородностей и использована математико-аналитическая модель упрочнения дискретных пород. Показано, что регулирование напряжений позволяет применять менее затратные технологии погашения выработанного пространства. Дана оценка возможности использования в составе твердеющей хвостов обогащения, кучного выщелачивания гидрометаллургии, шахтных вод, золы электрофильтров и сточных вод ТЭЦ. Рассмотрены вопросы экологическая безопасности. Результаты исследования могут быть полезны при модернизации действующего и проектировании нового горного производства.

Ключевые слова: сложноструктурное месторождение, подземная разработка, твердеющая смесь, окружающая среда

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Introduction

Complex structure metal deposits are, in most cases, composed of hard rocks and characterized by irregular shapes and placement in the earth's crust and a tendency to accumulate and release stresses (fig.1). [1-3].

Fig.1. Structure of the Ishimskoye deposit (Kazakhstan): 1– tectonic disturbances; 2–layered deposits; 3– ore bodies

Ore production is associated with damage to the environment which increases as the mining conditions become more complicated [4-6].

The preservation of the natural-technical system is facilitated by development technologies using hardening mixtures for filling of mined-out spaces, the share of which is limited by the high cost of their components [7-10].

Methods for determining the strength of filling mixtures depend on the depth of workings, an increase in the arch height of the overlying rocks, an increase in the stress of the developed massifs and a change in the properties of the rocks that compose these massifs under load [11-14]. In this case, the weakening of the rocks is balanced out by an increased strength of the hardening mixture [15-17].

One of the development trends in mining production is increasing the range of technologies using the filling of mined-out spaces with hardening mixtures; it is to replace the traditional components of the mixture with recyclable waste from mining and related industries [18-21] with an increase in their activity in disintegrator-type devices, combining the phenomena of mechanical and chemical activation [22-25].

The importance of technologies using the filling of mined-out spaces with hardening mixtures is assessed in various works, including those of Russian mining specialists [26-30]. The purpose of this article is to detail the concept of improving the extraction and processing of ores in the current state of mining production.

Research Methods and Materials

Research of deposit features and analysis of their development results, mathematical and analytical modeling of the relation between the strength of artificial massifs and the size of workings, generalization of data on the possibility of transferring the massif to the volumetric compression mode, mathematical modeling of the technology efficiency, assessment of the possibility of using waste.

The research uses generally accepted devices, equipment and methods.

Research results

Geomechanical aspect.

The estimated and actual strength indicators of hardening mixtures differ by 20...50%. The overwhelming majority of filled stope workings are filled with mixtures with a strength of 60...70% and not up to the roof of the chambers, but this, in the overwhelming majority of cases, is not accompanied by the destruction of massifs and the earth's surface above them.

This can be explained by vaulted structures formed of self-wedging rocks, ensuring the stability of the workings while maintaining the flat shape of the roof (Fig. 2).

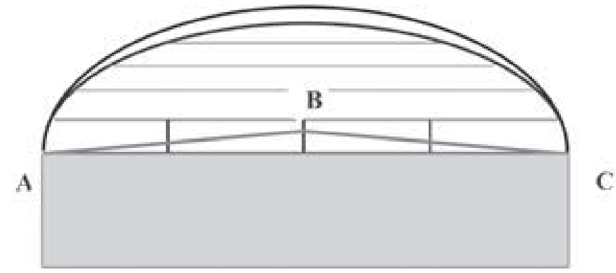

Fig. 2. The scheme of preserving a flat roof in case of an articulated arch: A, B, C – are the hinges of the arch

The interaction of stresses is described by a mathematical-analytical model [Golik, 1990]:

$$\sigma_1 \pm k\sigma_{2,3} = \sigma_{\text{сж}} = \left[\begin{array}{l} \sigma^0_{\text{сж}} = \int_0^{L_{0\max}} f(x)(dx_1, dx_2 ..., dx_n); \\ \rightarrow \left[\begin{array}{l} \sigma_{\text{закл}} = \int_0^{L_{0\max}} fx(dh_u) \\ \sigma_{\text{закл}} = \int_0^{L_{0\max}} fx)(dh_u + dh_c) \end{array}\right. \\ \sigma^{\text{ост}}_{\text{сж}} \text{ при } h_c > H; \sigma_{\text{закл}} = \int_0^{B} dx(dH), \end{array}\right.$$

where s_1 is the vertical intensity, mPa; $s_{2,3}$ –is the horizontal intensity, mPa; $\sigma_{\text{сж}}$ – is the intensity in the upper layer of the zone of influence, mPa; $\sigma_{\text{сж}}{}^{o}$ – is the intensity in the bottom layer of the zone of influence, mPa; L_{0max} – is the flat outcrop span, м; x_1, x_2... x_n – is the massif properties; $\sigma^{\text{ост}}_{\text{сж}}$– is the residual strength of rocks under uniaxial compression, mPa; $\sigma_{\text{закл}}$ – is the strength of filling under uniaxial compression, mPa; h_c– is the height of weakening zone, m; h_u – is the height of artificial massif, m; *B*– is the width of collapse zone, m; *H* – is the height of collapse zone, m.

Preservation of the earth's surface is ensured by filling the mined-out space with hardening mixtures with optimization of parameters by transferring the massif to the volumetric compression mode.

The preservation of natural and artificial massifs is ensured by a set of measures:

– sloping the artificial massif towards the ore (Fig. 3);
– drilling blast holes contacting the filling mass;
– strengthening the wall rocks;
– releasing the stored ore under an artificial ceiling.

Substandard ores with low content of useful components and tailings from their processing stages can be used as filling material.

Example. At a mining enterprise in Kazakhstan, smelter slags were activated in a disintegrator, converting up to 55% of raw materials with a particle size of -0.074 mm into an active state (Fig. 4).

The profit from using the technology with the filling of the mined-out space is described by the formula:

$$П = \left[\left(Ц - З - \left(У + З_у\right)\right)\right]\frac{1}{1 + E^{t-1}}$$

where *П*– is profit, rubles; *Ц* – is the value of the final product, rubles; *З* – is the cost of the final product, rubles; *У* – is environmental damage, rubles; $З_y$ – is the cost of eliminating environmental damage, rubles; E is the time discount coefficient, fr. unit; t is time.

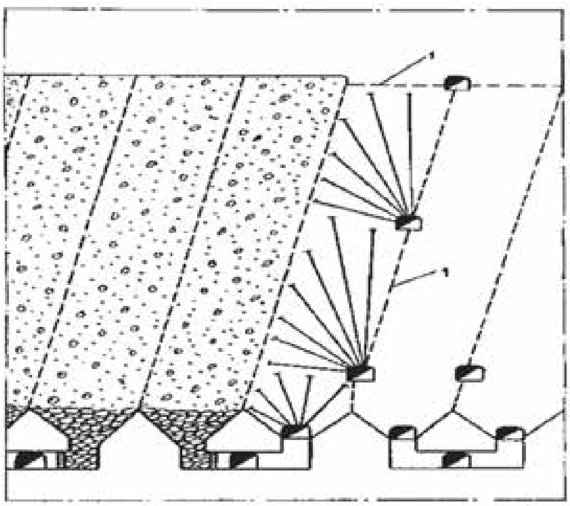

Fig. 3. The slope of the filling mass towards the ore:1 –shielding gap

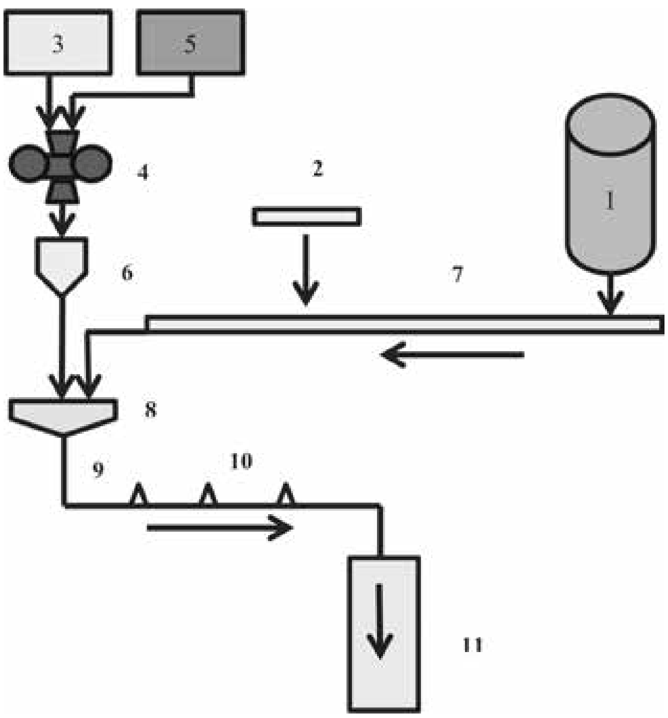

Fig. 4. Scheme of complex activation of hardening mixtures: 1 – cement; 2 – inert fillers screen; 3 – slag; 4 – disintegrator; 5 – water; 6 – vibrating mill; 7 – conveyor; 8 – mixer; 9 – laying pipeline; 10 – vibrators; 11 – block chamber

Results and Discussion

Mining-geological and hydrogeological conditions of solid mineral deposits are best suited by mining technologies for building up massifs from hardening mixtures. Optimization of the standard strength of concrete consists in reducing the time it takes to transfer it to a state of volumetric compression.

The binding properties of additives are increased in activators or by introducing additives into their composition: sodium and calcium chlorides, phosphogypsum hemihydrate, building lime, etc.

The first group of additives includes granulated slags, ash from thermal plant electrostatic precipitators, and other low-grade binders with low hydraulic activity. The second group includes inert materials – rock, sand, tailings from enrichment plants, etc.

Activation of materials allows increasing production volumes, returning waste storage areas to economic circulation and reducing the negative impact of waste on the environment.

Reduced cement consumption is achieved by regarding the massif condition when selecting the concrete mix composition for different sections of the object. For sections with increased stress concentration, a hardened composition is used, and for sections of less stressed rocks, a composition of lower strength is used.

The use of sodium sulfate salts, sodium chloride and active waters in concrete compositions improves the strength and rheological properties of hardening mixtures, which become more homogeneous, their ultimate shear stress decreases by 15-25%, and their strength increases by 2-3 times.

Cement consumption is reduced by using tailings dam water.

One of the innovative technologies is the use of high-speed mills - disintegrators, the fundamental difference of which is that the enrichment tailings are mechanically activated while the metals are simultaneously chemically extracted from them.

The economic efficiency of tailings disposal is based on the cost of the metals obtained, raw materials for the construction industry and the reduction of environmental damage from tailings storage.

Conclusions

1. It has been established that rock structures arising in massifs make it possible to reduce the strength requirements for massifs made from hardening filling mixture or to leave voids unfilled.

2. It has been confirmed that the experience of preparing, transporting and placing hardening filling mixtures allows us to objectively assess the prospects for using low-cost technologies for the reclamation of mined-out spaces and determine the directions for further development of massif management during underground mining.

3. A tendency has been established to reduce the deficit of components of the hardening filling mixture by activating its components.

REFERENCES

1. Golik VI, Dmitrak YuV, Komashchenko VI, Razorenov YuI. Ecological aspects of ore tailings storage in the mining region. *Ecology and industry of Russia*. 2018;22(6):35-9 (In Russ.). https://doi.org/10.18412/1816-0395-2018-6-35-39.

2. Klyuyev RV, Bosikov II, Mayer AV, Gavrina OA. A comprehensive analysis of the use of effective technologies to increase the sustainability of the natural and technical system. *Sustainable development of mountain territories*. 2020;(2):283-90 (In Russ.). DOI:10.21177/1998-4502-2020-12-2-283-290.

3. Lyashenko VI. Improving the safety of underground mining of deposits of complex structure. *Mine Surveying and Subsoil use*. 2019;1(99):23-36 (In Russ.).

4. Einbinder II, Patskevich PG, Krasyukova EV. Substantiation of the parameters of hazardous zones in the combined development of kimberlite deposits in Yakutia. *Izvestiya Tula State University*. *Earth Sciences*. 2019;(3):48-60 (In Russ.).

5. Adero NJ, Drebenstedt S, Prokofieva EN, Vostrikov AV. Spatial data and technologies for geomonitoring land use in the aspect of the development of the mineral resource sector. *Eurasian Mining*. 2020;(1):69-74. DOI: 10.17580/em. 2020.01.14.

6. Wen J, Li H, Jiang F, Yu Zh, Ma H. et al. Assessment of the risk of rock destruction based on the equivalent strength of surrounding rocks. *International Journal of Mining Science and Technology*. 2019;29(4):571-76.

7. Khairutdinov AM, Kongar-Suryun ChB, Kovalik T, Tyulyaeva YuS. Management of the stress-strain state of a rock mass by forming a multi-strength bookmark. *Mining information and analytical bulletin*. 2020;10:42-55. DOI: 10.25018/0236-1493-2020-10-0-42-55.

8. Yin S, Shao Y, Wu A, Wang H, Liu X, et al. A systematic review of the technology of production of pasty materials in metallurgical mines for cleaner production in China. *Journal of Cleaner Production*. 2019;247:19590.

9. Qi Ch, Fourier A. Backfilling from cemented mass for the management of tailings dumps of minerals: an overview and prospects for the future. *Mineral engineering*. 2019;144:106025.

10. Bumanisa G, Bajarea D. The effect of a sandy microfill on the strength of a cement mortar under compression obtained by collisional grinding in a disintegrator. *Procedia Engineering*. 2017;172:149-156. DOI: 10.1016/j.proeng.2017.02.037.

11. Protodiakonov MM. Rock pressure and mine fastening. Part 1. Rock pressure. 3rd ed. M.-L. Novosibirsk: GNTI, 1933. 127 p. (In Russ.).

12. Dinnik AN. On rock pressure and calculation of round shaft support. *An engineering worker*. 1925;7:1-1

13. Slesarev VD. Mechanics of rocks. M.: Ugletekhizdat, 1948. 303 p. (In Russ.).

14. Flores G, Catalan A. Transition from a large open pit to a new geometry of block collapse in the “macroblock version” at the Chuquicamata mine, Chile, Codelco. *Journal of Mining Mechanics and Geotechnics*. 2019;11(3):549-61.

15. Trofimov AV, Kirkin AP, Rumyantsev AE, Yavarov AV. Application of numerical modeling to determine the optimal parameters of the method of complete core unloading when evaluating the stress-strain state of a rock mass. *Non-ferrous metals*. 2020;(12):22-7. DOI: 10.17580/tsm.2020.12.03.

16. Liang W, Zhao G, Wang X, Zhao J, Ma Ch. Assessment of the risk of rock collapse in deep mines using multi-criteria approaches to distance-based decision-making using uncertain fuzzy information. *Engineering geology*. 2019;260:105211. https://doi.org/10.1016/j.enggeo.2019.105211.

17. ang VK, Vo TH, Do NA, Dao VC. Stability of Deep Underground Mine Drift through Complex Geology Conditions in Quang Ninh Coal Area. *Journal of the Polish Mineral Engineering Society*. 2020:221-30. https://doi.org/10.29227/IM-2020-02-27.

18. Khairutdinov MM, Kongar-Suryun ChB, Tyulyaeva YuS, Khairutdinov A. Cement-free filling mixtures based on water-soluble technogenic waste. *Izvestiya Tomsk Polytechnic University. Georesource engineering*. 2020;331(11):30-6. (In Russ.).

19. Khairutdinov A, Paleev I, Artyomov S. Replacing traditional components of the filling mixture with man-made waste. *IOP conference series: Science of the Earth and the environment*. 2021;904(1):012005. DOI: 10.1088/1755-1315/942/1/012005.

20. Simser BP. Management of mining operations at Canadian mines for the extraction of hard rocks. *Journal of Mining Mechanics and Geotechnical Engineering*. 2019;11(5)1036-43.

21. Chen G, Chen J, Peng J. The effect of mechanical activation on the structural and microwave absorbing characteristics of high-titanium slag. *Powder technology*. 2015;286:218-22. DOI: 10.1016/j.powtec.2015.08.021.

22. Golik VI, Razorenov YuI, Dmitrak YuV, Gabaraev OZ. Trends in the development of the mineral resource base of non-ferrous metallurgy of Russia. *Izvestiya Tulskogo gosudarstvennogo universiteta. Earth Sciences*. 2019;(2):117-28. (In Russ.).

23. Drebenstedt K, Golik VI, Dmitrak YuV. Prospects for diversification of metal mining technologies in the Russian Federation. *Sustainable development of mountain territories*. 2018;(1):125-31. (In Russ.).

24. Dzaparov VKh, Kharebov GZ, Stas VP, Stas PP. Investigation of dry building mixes based on industrial waste for underground construction. *Dry building materials*. 2020;(1):35-8. (In Russ.).

25. Komashchenko VI. Ecological and economic expediency of utilization of mining waste for the purpose of their processing. *Izvestiya Tula State University. Earth Sciences*. 2015;(4):23-30. (In Russ.).

26. Tuokuu FH, Kpinpuo SD, Hinson RE. Sustainable development of the gold mines of Ghana: a view of stakeholders. *Journal of Sustainable Mining*. 2019;18(2)77-84. DOI: 10.1016/J.jsm.2019.02.007.

27. Bloodworth A, Gunn G. The future of the world sector of minerals and metals: problems and challenges for the period up to 2050. *Earth Sciences*. 2012;15:90-7.

28. Dominguez Maria S.K., Baptista Adelina L.F., Diogo Miguel Tato. Integrated engineering systems used for risk management in the mining industry. *International Journal of Mining Science and Technology*. 2017;27:611-16.

29. Maede Tayebi-Khorami, Mansur Edraki, Glen Corder and Artyom Golev. Rethinking mining industry waste through an integrative approach based on the pursuit of a closed-loop economy. *Minerals*. 2019;(9):1-13. DOI 10.3390/min9050286.

30. Zhou X, Nguyen H, Hung VT, Lee C-W, Nguyen V-D. Application of adaptive neuro-fuzzy inference system and differential evolutionary optimization for predicting rock displacement in tunnels and underground spaces. *Structures*. 2023;48:1891-906. DOI: 10.1016/j.istruc.2023.01.059.

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