Nature-like equipment for backfilling the mine chambers to reduce the risks of technogenic seismic impact

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Abstract. The priority task in the mineral industry is to increase the efficiency of the exploited and infrastructure, equipment, including the creation of transport systems that have high performance while reducing the cost of transporting mineral raw materials and products of its processing. One-third of the world’s mining companies use their mining systems at their enterprises to create a space. Backfilling activities are carried out in order to improve the safety of mining operations, namely, to control mining pressure, reduce possible mineral losses during excavation, prevent the occurrence of underground fires, as well as sudden outbursts of coal and gas, protect against destruction of objects in residential areas. Particular attention should be paid to the use of hydro-folding as a measure to prevent technogenic-tectonic earthquakes during long-term and continuous development of deposits. Taking into account the peculiarities of the materials used as a base when preparing filling mixtures, the specificity of the process of moving them to the bookmark site, necessary for obtaining a backfill array of required characteristics, is becoming increasingly important to use fundamentally new transport technologies for filling mixtures.

1. Introduction
The laying of the spent space allows controlling the mining pressure and improve the safety of mining operations, conducting mining at the same time by underground and open methods, increasing the percentage of mineral extraction, and also reducing the negative impact on the environment.

The factors that have the main influence on the increase in risks from the man-made seismic regime of mine workings are their age and the number of depleted layers, as well as the fact of the backfilling and the type of filling material used [1, 2].

2. Materials and methods
The laying of the worked-out space is used to reduce the deformations of the water barrier to protect against the flooding of workings and to reduce the subsidence of the earth's surface under residential areas. In addition, it is possible to increase the volume of recoverable mineral resources, improve the conditions for ventilation of existing mine workings, reduce the area of land allocated for dumps and thus reduce the amount of land intended for remediation [3]. Waste enrichment with impurities of insoluble materials, as well as clay-salt wastes are used as filling material [4]. Nowadays, about 85% of the bookmark is held hydraulically and only 15% is mechanical [5]. According to the research work [6], the laying of voids in the workings as a measure to prevent flooding of the developed space is
mandatory on 2 layers with 3 development, as well as under the condition of conducting excavation work under the planning structure of the city.

![Image](image_url1)

![Image](image_url2)

![Image](image_url3)

![Image](image_url4)

**Figure 1.** Surface collapse caused by failure of mine workings: 1, 2 - Solikams; 3, 4 - Novokuznetsk

After the completion of the laying of waste voids in one of the ways, during a certain time, the array shrinks in the vertical and horizontal directions. In addition, the formed massif under the pressure of its own weight is additionally compacted and deposited in vertical projection. To illustrate this fact, the authors used the data of B.A. Borzakovsky, who writes that the shrinkage of the array during the dry laying of the VKMKS ends mostly after 8-12 months. After shrinkage, an increase in the strength of the array occurs. This process is much slower. Hydraulic laying gives a more rapid decrease in the average density of the seismic energy released, as opposed to dry (about 10 years faster) [7].

The study of the long-term impact of work on the laying on the seismic potential of the workings shows that these works contribute to the stabilization of the disturbed rock mass not by a one-time decrease in the intensity of its destruction, but as a decrease in the period of seismic activity after the laying. The study of workings with the use of backfill materials of various compositions allowed to establish that the hydraulic folding leads to earlier (about 10 years earlier) attenuation of seismicity (Fig. 2) [8].

![Graph](graph_url1)

![Graph](graph_url2)

![Graph](graph_url3)

**Figure. 2** Dependence of seismic energy release density on the age of the filling works:

- ◊ - hydraulic laying, † - dry laying

When transporting the filling mixture into the produced chamber, it is impossible to feed it under the roof of the mine, which leads to the appearance of unfilled cavities in (Fig. 3). The consequence of incomplete bookmarks is the subsidence of the roof of the mine, disruption of the continuity of the backfill array being formed, as well as the formation of channels for water breakthrough [9,18].
The bearing capacity and stability of backfill arrays is not sufficiently realized due to the lack of full-fledged contact with the overlying mass over the entire surface of the mine. The incompleteness of the laying of the developed rock volumes is one of the main factors contributing to the displacement of the masses being worked on [10].

The use of measures for the laying of voids formed during the extraction of minerals requires the construction of special filling complexes, which is associated with significant financial investments. In addition, the use of the complex on the laying of workings significantly complicates the technological scheme of the process of mining. The stowage complex is a complex system introduced into the composition of a mining enterprise with its own technological processes, the violation of one of which can lead to a malfunction of the entire enterprise.

The lack of efficiency of the complex on the tab inhibits the growth of enterprise productivity and access to new capacity. For example, at the Komsomolsky mine (Russia, Norilsk), an increase in production volumes led to the need to increase the production of backfill mixes from 0.95 million tons to 1.25 million tons, which naturally required the modernization of the backfill complex.

The construction of a complex for laying a developed space is not able to solve all the problems on its own, as the question arises of transporting the filling mixture to the developed space [11]. The development of mining operations leads to the increase in the distance between the place of laying the mixture and the place of its preparation, which leads to the increase in the length of its transportation. For example, at the Buribayevsky GOK (Russia, Bashkortostan), the development of mining operations led to the removal of the clearing site from the backfill complex to a distance of about 3 km. Such removal made it extremely problematic to work with the use of a system with a bookmark at this mine, and it was ultimately decided to abandon it.

3. Discussion

The transportation of backfill material into the open space is the most important technological link in the chain of processes associated with the extraction of mineral resources. When pumping the filling mixture, a number of difficulties arise. For example, at the Gaysky GOK and the mines of the MMC Norilsk Nickel, transport to deep levels caused damage to the pipelines due to the occurrence of air strikes. In addition, when feeding slurry over large vertical distances, the question arises of sharp pressure fluctuations associated with starting and stopping pulp feed modes.

When moving the filling material to large horizontal distances, it becomes necessary to use various auxiliary equipment, since the kinetic energy of the filling mixture flow is insufficient due to high pressure losses. Moving the filling mixture through pipelines leads to their rapid deterioration due to the high abrasivity of the solid slurry fraction. At the same time, when the backfill material is moved with an insufficient flow rate, its separation and silting of the pipelines can occur, which leads to an uneven feed of the backfill material and, accordingly, deterioration of the quality of the monolithic
backfill.

For the transportation of hardening mixtures the pipes made of steel with a diameter of 76-220 mm and a wall thickness of 4-14 mm are usually used. The use of polyplastic pipes, which are characterized by high wear resistance and lower friction coefficient, is promising. At Uralkali, the use of polyplastic pipes made it possible to increase the service life of pipelines and increase the length of the horizontal section of the gravity flow pipeline, which led to a decrease in the cost of filling works [12].

In some designs of backfill complexes, the vibration method is used to prevent the occurrence and elimination of pipeline blockages caused by the separation of the transported material [13]. In an emergency case (with an increase in pressure in the line), the mechanisms that create a longitudinal vibration are activated at a particular section of the pipeline. As a result of vibration exposure, near-wall friction is sharply reduced, which makes it possible to eliminate blockages and siltation [14].

For the timely prevention of the occurrence of air strikes, which arise as a result of the increase in pressure when the backfill material vertically moves under its own weight to great depths, various devices are used. One example is a bleed dumping device used at the Thompson Mine (Canada) mine. Another example of a mechanism to prevent the occurrence of pneumatic shocks when transporting to great depths and sharp pressure fluctuations associated with starting and stopping modes during pulp feed is the use of a device to release excess air. To prevent emissions of filling mixture from the mouth of the pipeline at the mine "Tara Mine" (Ireland), a device is used that allows you to remove air from the pipeline.

It is also not uncommon in the production of a filling mixture of a situation where an excessive amount of water is added to it in order to increase its transportability, this leads to the separation of the mixture during transportation and, consequently, to a decrease in the strength of the filling mass. Thus, at the mines of the company “Outokumpu” (Finland) with the transition of cleaning works to deeper horizons, the side walls of the artificial pillars collapsed. In order to eliminate the negative effects of excess water the consumption of the binder increased in the mixtures, which led to an increase in the cost of production.

To improve the rheological properties, various chemical additives are introduced into the monolithic tab - plasticizers, catalysts (retarders and activators) of hardening. They allow increasing plasticity with less water consumption and a binder component, preventing the mixture from splitting, blocking the transport pipeline, adjusting too fast or slow hardening, helping to increase the mechanical strength of the array [15].

Most of the existing hydrotransport systems operate at low concentrations of solid material in the flow of the filling mixture, which leads to a decrease in the technical and economic efficiency of the hydraulic transport system, as well as to a significant increase in water inflow in the workings. In addition, in hydrotransport technologies, the dosage of material supply to the pipeline is insufficiently used, as well as adjustment and control of parameters, as a result, as a rule, the hydrotransport systems of mining enterprises operate in low-cost and unstable modes.

Efficient transportation of pasty filling mixtures by ground pumps causes difficulties due to the existing non-linear relationship between efficiency and solid phase concentration, as well as the kinematic viscosity coefficient.

Taking into account the peculiarities of the materials used as filling mixtures, an effective transportation process required to obtain a backfilling array of specified characteristics should be carried out under the following conditions:

• providing an intense physical impact on the mixed components to organize their movement along mutually intersecting trajectories;
• compliance with the optimal residence time of components in the transport line, to maintain the homogeneity of the filling mixture.

To implement such tasks, a fundamentally new technology of transportation of hardening filling mixtures with simultaneous impact on the material is necessary.
4. Conclusion
1. The well-known advantages of underground geo-technology of the development of mineral deposits with the laying of the worked-out space in some cases are not realized and require the improvement of the existing technologies used during the laying. Recently, the development of technology and related technologies, whose work is based on the principle of nature-similarity, has been actively developed.
2. The design of pumping equipment, in which the speed of movement of the filling material and the pressure developed by the pump, does not depend on the viscosity of the substance, but is directly dependent on the electrical parameters of the drive, will allow for efficient filling work in remote areas.

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