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Mechanism of Interaction of Backfill Mixtures with Natural Rock Fractures within the Zone of Their Intense Manifestation while Developing Steep Ore Deposits

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Abstract: Mining systems for ore deposit extraction with the backfilling of the goaf solve the problem of preserving the surface and the complete extraction of rich ores. This paper considers the filling of mined-out stopes with a viscous fluidal solution for the formation of an artificial strong massif, which results in a conglomerate formed on contact with the ore deposit. It was established that exogenous fracturing at the Pivdenno-Belozirske deposit significantly affects the stability of the sides and ceilings in the chamber. This phenomenon can be observed at the first stage of processing. At chambers (the second stage of processing), the artificial rock mass is exposed. It has been established that the chamber mining systems do not ensure the operational stability of the vertical outcrop in the zones of exogenous intensive fracture of the rock mass, especially in the places where they intersect. The zonal location of intense fracture was established along the strike and dip of the steep ore deposit, as was its importance in the formation of rock fallouts. An analytical solution algorithm has been developed to determine the penetration of the backfilling mixture in the plane of the intersection of zones of intense cracking, with opposite azimuths of incidence at steep angles of macrocracking. The features of penetration into microcracks of the backfilling mixture used at the mine, which are affected by their granulometric and physicochemical compositions, have been determined. The influence of the height of the layer and the procedure of backfilling the chamber space in the liquid phase on the formation of the necessary pressure for the opening of a microcrack was studied. The priority of backfilling the exogenous macrocracks with significant gaps and those between tectonic blocks with mixtures has been analytically substantiated and confirmed by experimental methods of research in the mine.

Keywords: mass fracturing; natural mass; ore deposit; zones of fracturing; backfill mixture; penetration; hydraulic pressure

1. Introduction

Complex mining and geological conditions of the occurrence of steep ore deposits with high contents of valuable components are developed by the underground method; to prevent considerable disturbance of the land surface, the mined-out spaces of stopes are filled with backfill mixtures to form an artificial massif [1–3]. The extraction of ore deposits along the strike forms a rock mass consisting of the natural fractured mass and artificial voids in the form of mine workings, large stopes, and an artificial monolithic massif [4,5]. The physico-mechanical properties of the latter vary during the mining operations [6–8].

In terms of rock masses, one can observe a network of exogenous and endogenous fracturing with the azimuths of sub-meredial and sub-latitudinal strike and different angles of propagation that are complemented by tectonic disturbances [9]. Rock mass disturbances are peculiar in different fracture frequencies that form zones of intense fracturing, monolithic zones, and zones of stable fracturing [8,10]. Being in close contact with the artificial backfilled massif, and due to minor tensile stress in the latter, the fissured ore mass provokes the caving of the critical conglomerate mass with the further development of a caving chain of the backfilled area [11,12]. Such actions can be driven by a seismic effect from blasting operations [13], and the nonobservance of the parameters of borehole location on the contact with the artificial massif [14].

The analysis of previous studies showed that the ore has more than six fracture systems with different intense and certain regularity [15]. The revealed regularity corresponds to the location of continental stresses that are formed in tectonic blocks [16–18]. The zones of the dominant exogenous fracture systems are subordinate to them [19]. This statement is confirmed by space mapping of the lithosphere on the continents [16,19]. The impact of mineral extraction on the change in the stress–strain state in the rock massif has been established. The effect of regional stress fields on the safety of mining operations is determined [20,21]. The seismic influence on the resistance of the rock mass to exposure was considered [22,23]. The safety aspect of ore extraction was established, both with an open space and with the backfilling of the goaf [24–26]. The resistance of the rock mass to the clogging of the ore mass [14,27] and the possibility of adjusting the technological parameters of the mining systems were established [28,29].

It is known that the parameters of the chambers depend on the stability of the ore exposure plane under the influence of mining pressure and the seismic effect [30–32]. The response of the backfilled rock mass to destruction under the action of three axial loads was determined [33].

The study of the backfilling mixture in the flow phase has had enough attention devoted to it in works [34,35]. The strength characteristics of the artificial rock are highlighted in works [36]. The composition of the backfilling mixture is selected in such a way as to resist the action of mining pressure, to prevent the appreciable deformation of the Earth's surface in underground mining operations [37,38]. The consequences of clogging with embedded ore material are considered in works [39,40]. The regularity of the depth of penetration of the liquid state of the backfilling mixture into the ore or rock mass from the size of the crack opening, the coarseness of grinding solid fractions, and the hydraulic pressure of the embedding mixture were revealed [41–44].

The mechanisms of interaction of the backfill mixtures within the zones of intense fracturing of the natural rock mass on the stability of the vertical plane of stope outcropping while developing steep natural rock are not studied enough in terms of the effect of lateral thrust of both artificial and ore masses represented by a pillar between the stopes of the first and second stage of ore deposit mining.

The purpose of the study is to substantiate the mechanisms of penetration and formation of an artificial rock mass in the zone of intersection of the predominant systems of intensive fracturing.

Achieving this goal is determined by solving the following problems: determination of the main systems of exogenous cracks in the zones of their intensive location in the ore; investigation of the granulometric and physical–chemical composition of the backfilling mixture; development of an analytical solution for determining the penetration of the mixture in the plane of the intersection of zones of intense cracking with opposite azimuths of fall at steep angles of macrocracking; and revealing the creation of a monolith in the intersection zones of intense fracture during the mining of an ore deposit.

2. Geotechnical Features of Mining of the Pivdenno-Bilozerske Iron Ore Deposit

The performed analysis established that the Pivdenno-Belozerske deposit of rich iron ores is represented by the "Holovna" deposit, whose ore reserves are exploited by Zaporizhzhya Iron Ore Combine (Ukraine). A subsurface chamber system of mining was used, with below-surface reflection of the ore and backfilling the goaf with hardening mixtures. The dip of the ore deposit was easterly, at an angle of 60° to 80°. The maximum thickness of the deposit was 150 m in the southern part of the mine field; the minimum was 10 m in the northern part. Quartz-chlorite-seracite schists with a strength of 60–90 MPa were on the lying side. Layers of quartzites with a thickness of up to 10 m are often found. The uphill side of the northern part of the deposit is represented by ferruginous quartzites, strong, fissured and stable, with a strength of 120–160 MPa. In the southern part of the hanging side, the rocks are like the lying side. Ores are hematite-martite and mart-to-hematite, with frequent transitions from one type to another. Most of the ores have a strength from 30 to 120 MPa, with weak cracking, low and medium strength. The developed system of exogenous vertical and sloping cracks has an angle of incidence of 10–20° and 80–85°. The ore is exposed along the plane of the cracks. The stability of the ore is low over the entire plane of the deposit. The azimuth of the fall of vertical cracks in the direction of 260° prevails, and the slope is of 160–185° [45].

The iron content is 60–67%. Ore reserves have been mined in the depth intervals of 340–740 m. Currently, mining operations are carried out in the layers of 840–940 m. The ore area of the horizons decreases with depth. Figure 1 shows the horizontal area of the extracting horizon 875 m).

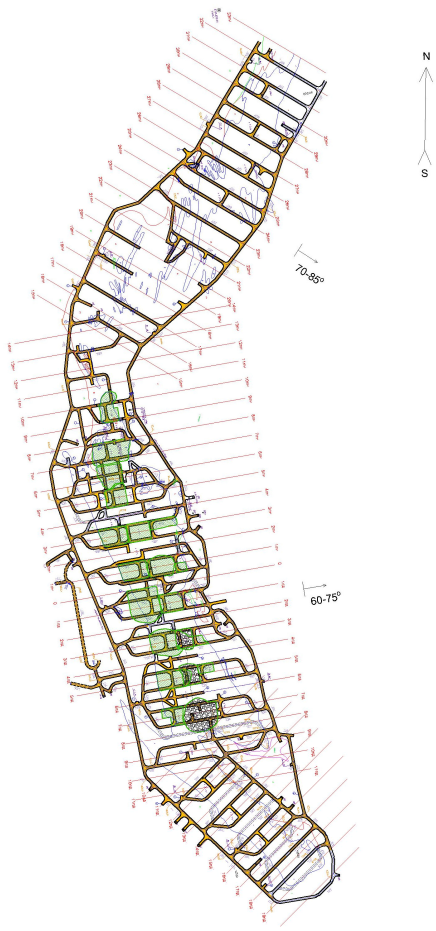

Figure 1. Section of the ore deposit with mining operations along the extracting horizon, 875 m.

On the ore area, the chambers are worked out in groups through a barrier equal to the width of the chamber. The dimensions of the chambers are (m): height 80–120, width 15–30, length 40–60, respectively. In the central and southern part of the deposit, two to three chambers have transversely extended deposits, and in the northern part there is one. The extraction of ore reserves along the strike forms a rock mass consisting of a natural fissured mass with its own properties, artificial cavities in the form of mining workings, and large-sized chambers. The physical and mechanical properties of the artificial mass change over the time.

To fill the goaf, the following composition of the mixture (per 1 m^3) were used in the following variations: binding material-furnace granulated slag (500–600 kg); inert aggregate-limestone (900–1000 kg) and crushed rock (500–600 kg); water—350–400 L. Depending on the distance of transportation of the mixture, the water content and ratio of the components varied. The preparation of the backfilling mixture was carried out on a surface complex with a capacity up to 300 m^3/h. The crushing of the furnace granulated slag was carried out by wet grinding in two ball mills MShTs (МШЦ—original name) 3.6 × 5.5 with a capacity of 60 t/h. The yield of the fraction was 50–60% of particles with a size of 0.074 mm. The pulp density at the exit from the mill ranged from 1.45 to 1.55 g/cm^3. The mobility of embedded mixtures was within 10–12 cm (sediment cone). The components of the mixture were mixed in the mixer and delivered by pipeline transport to chambers. Here, the hardening and formation of a monolithic artificial massif took place. The strength of the collateral array reached the standard strength of 8 MPa after 90 days. Annually, 1.0–1.2 million m^3 of collateral mixture is prepared for the laying of underground cavities on the surface complex.

3. Materials and Methods

In this study, the mechanism of penetration of mixtures deposited into the zone of intense fissures of the rock mass is considered for the conditions of working out iron ore with solidifying at PrJSC Zaporizhzhya Iron Ore Combine (Ukraine). To solve the mentioned problems, an instrumental method of researching the manifestation of fissures in the mining workings of the "Holovna" ore deposit of the "Expluatatsijna" mine was involved. Analysis of the geological surveying documentation was performed. Instrumental research was conducted according to the standard methodology. A mining compass, feeler gauge and tape measure were used to detect the depth of the crack openings and the distance between them. Measurements were carried out directly in the holes of ores during their passage through the ore deposit in the working horizons for several years. At the same time, visual observation of cracking and photo–video recording was conducted. The location and manifestation of exogenous systems in the ore mass was established. It was provided by the extrapolation method of the obtained measurement results and their comparison with the data of geological surveying documentation. The Schmidt palette was built. The leading cracking system was identified based on the number of manifestation measurements. The exposed area of the sides of chambers and the backfilled rock mass was from 4000 to 6000 m^2, and more at a height of up to 200 m. Dropouts were visually observed and chamber parameters were defined using a laser measurer. The filling of exogenous cracks open with sufficient gaping with concrete mixtures was established by the indirect method of releasing the crushed mining mass in the pits by the photo-confirmation method.

The mineral composition of the backfilling materials was studied using X-ray phase analysis on the diffractometer DRON-2. Finely dispersed samples of granulated blast furnace slag and flux limestone with a grain size less than 0.06 mm were prepared. The interplanar distances (d) at the reflection intensity (I) were recorded. According to the reference data, the minerals included in the backfilling mixture were identified.

According to the backfilling technology, the chamber was filled with the mixture by layers to the total height, at least 6–8 m. The blowing of the mixture was stopped for at least 16 h after preparing each layer. At the height of the jumpers, the backfilling should stop until the water drainage and the loss of mass mobility have completely stopped, in accordance with the composition of the used backfilling mixture. Then, after backfilling the upper bridge, the filling of the chamber is carried out continuously until the roof of the chambers is reached, or the distance between the roof of the chamber and the level of the backfilling does not reach 1.5–2 m. When determining the height of the backfilled layer, only the level at the bridges is considered the angle of spreading, which is within 7–10°.

Considering the existing technology of filling the goaf, the authors developed a calculation scheme and analytical determination of the parameters of the mixture penetration into the intersection zone of the intensive fracturing.

The solution to establishing the mechanism of the penetration of the mixture into the depth of the intersection zone of intense cracking is based on the theory of Newtonian fluids to consider the process of the formation of an artificial mass based on the plastic properties of the filler particles in the mixture, which correspond to the analogous Coulomb friction under the action of static stresses.

4. Results and Discussions

4.1. Analysis of the Distribution of Intensive Fracturing in the Ore Mass

The analysis of the distribution of fracturing was provided in the mining and geological conditions of the "Eksploatatsijna" mine of the Pivdenno-Bilozerske deposit. A study of the manifestation of cracking on the northern and southern flanks of the "Holovna" deposit in ores 3-north +15 in horizon 715 m, 2-north +15 in horizon 690 m, 3-north +15 in horizon 640 m, 2-south +7.5 in horizon 740 m, 1-south +15 in horizon 715 m, 17-south +15 in horizon 665 m, 13-south +15 in horizon 640 m, 8-south +7.5 in horizon 635 m, 5-south +15 and 6-south +15 in horizon 810 m, 7-south +15 in horizon 740 m and loading entrance #1 in horizon 825 m was carried out. The number of measurements was 16 on the northern flank and 32 on the southern flank.

Based on the results of the measurements, the leading systems of exogenous fracturing were established based on the Schmidt palette (Figure 2).

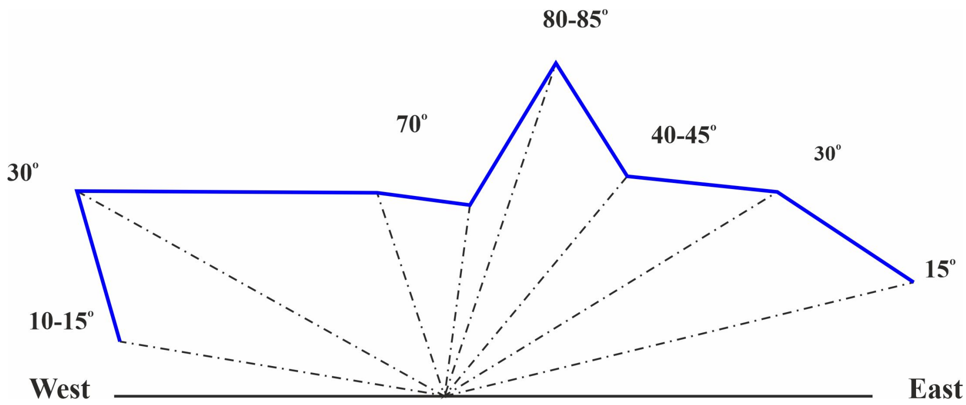

Figure 2. Distribution of azimuths and dip angles at the "Holovna" ore deposit according to the Schmidt diagram.

It was established that most of the cracks have an eastern dip with an azimuth of 260–275° and an angle 10–15°; 30–35°; 80–85°, along which ore blocks are exposed. The dip of the ore deposit is easterly at an angle of 65–72° (Figure 3a). Tectonic disturbances are accompanied by variously directed anticipatory cracks of I-III orders; ore stability is low (0–2 cracks per one meter). This is characteristic of zones of intense fracturing. Often, there are cracks of the I-II-III order, often opened. In this case, the stability is very low (20 cracks per one meter). The main and end systems of cracks of the open type (crack opening is 14–80 microns) are less common. They fall to the west at an angle of 30–70°. In the south, there are mainly fracture systems with a dip to the southwest at an angle of 15–25°, along which ore exfoliation is possible. The penetration of the backfilling into an open crack with a gap of 70–80 mm is shown in Figure 3b.

(**a**) (**b**)

Figure 3. Photographs of cracks in the ore mass (**a**) and pieces of the backfilling material in the pipe (**b**).

On the northern flank of the ore deposit, the fracturing is medium and tectonic cracks are observed at an angle of 40–45°, multi-directional, often of the open type, forming open cavities filled with crushed material. Cracks falling to the northeast and at an angle of 15–30° to the east have been established.

Based on the results of research, it was established that the main exogenous fracture systems, which manifest themselves as zones with very low and low stability, can be considered systems with dip azimuths of 260–275° and angles of 10–15°; 30–35° and 80–85°.

4.2. Research of the Backfilling Mixture Parameters for the Formation of an Artificial Rock Mass in the Goaf

Fluxing limestone with the size up to 5 mm, blast-furnace ground slag to 50–60% residue of 0.074 mm and water-hydrated crushed rocks of 20 mm were used as a backfill mixture [45]. The specific surface of slag particles was 2000 cm^2/g.

Studies have shown that the artificial massif strength grows along the increasing specific surface of slag particles and limestone. Chemical composition forms new crystalline formations and affects its strength. Calcium silicates are the main component, as $CaO/SiO_2 > 1.5$ in the structure of a backfill mixture.

As a result of the research, it was established that blast furnace slag (Figure 4a) contains melilite, which is similar in composition to ockermanite, and pseudowollastonite. The X-ray pattern of melilite includes diffraction peaks (d/n = 4.25; 3.03; 2.8; 2.29; 1.7; 1.67; 1.37). The main diffraction maxima correspond to pseudowollastonite (d/n = 2.8; 1.96; 1.82; 1.47). The advantage of the intensity of the diffraction maxima of melilite over pseudowollastonite indicates its greater content in blast furnace slag.

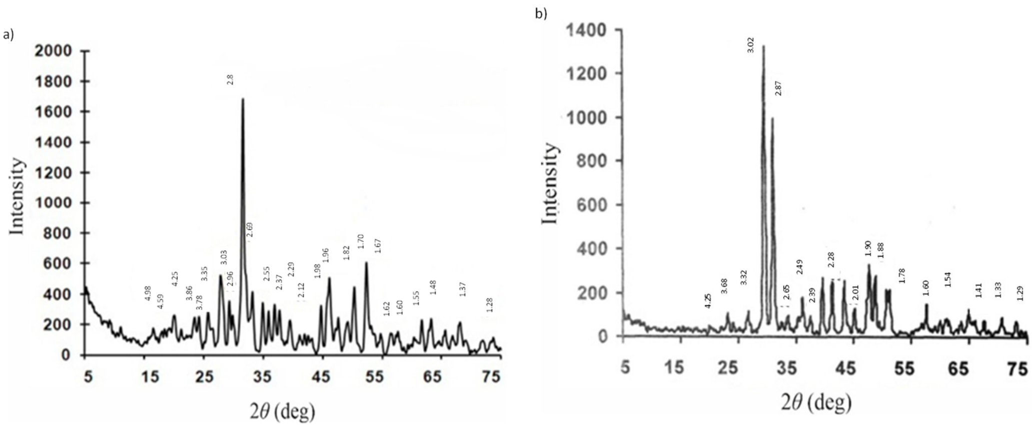

Figure 4. Diffractograms of embedded materials: furnace slag (**a**); flux waste (**b**).

The results of the flux waste research (Figure 4b) showed that it contains calcite (d/n = 3.029; 1.912; 2.28), dolomite (d/n = 2.65; 1.78; 1.54) and, as an impurity, wollastonite (d/n = 2.18; 1.76; 1.92). The minerals melilite, pseudowollastonite and, to a lesser extent, calcite and dolomite take an active part in the hydration process in the backfilling mixture.

The impossibility of the penetration of crushed rock (size 20 mm) into the cracks (within 14–80 microns) was established, even under the conditions of unloading the rock mass under the action of blasting. The crack will be filled with small fractions of ground slag, which contains melilite similar in composition to ockermanite and pseudowollastonite.

4.3. Analytical Determination of the Penetration Parameters of the Backfilling Mixture into the Crossing Zone of Intensive Fracture of the Ore Mass

It was found that, in the chamber, the backfilled mixture spreads along a horizontal plane with a spreading angle φ = 7–10° under the action of gravitational forces. The filtration of the artificial rock mass from the water drainage is directed towards the sides of the goaf. The waterfall occurs on the sides of the rock mass, forming a weak contact with the monolith rocks.

Based on the results of the research, the authors developed a calculation scheme and proposed an analytical determination of the parameters of the penetration of the backfilling mixture into the intersection zone of intense fracture of the ore mass which take into account the technological features of filling the goaf to the fixed height h and installing insulating jumpers in the preparatory and mining works (Figure 5). Zones of intensive cracking appear with certain periodicity in the sides of the ore deposit at height h_1.

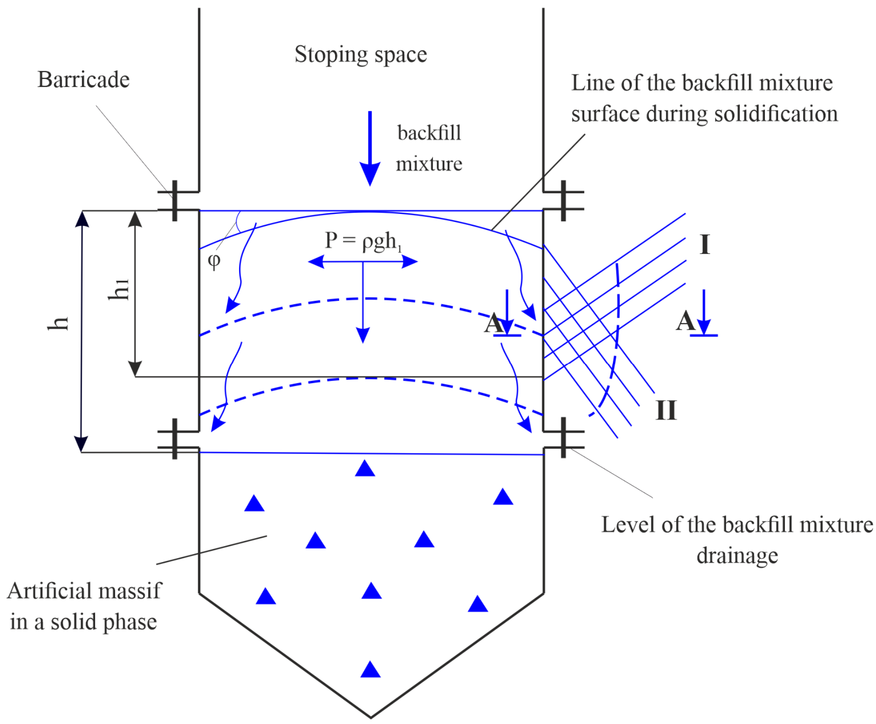

Figure 5. Scheme of backfill mixture penetration into the intense fracturing zone of the ore deposit.

The authors considered the flow through fracture systems of a viscous-plastic backfilling mixture, which is composed of furnace slag, dolomite, rocks, and water. The zone of intense fracturing of the rock mass is represented by systems I and II, which intersect at sharp angles with the opening in the first δ1 and second system δ2 (Figure 6). The distance between the cracks in the first system is l_1 and in the second system l_2. The backfilling mixture comes to them with a constant flow rate Q (point 0). In the horizontal plane, each segment between the points of the crack crossing nodes can be represented by the vectors of filling.

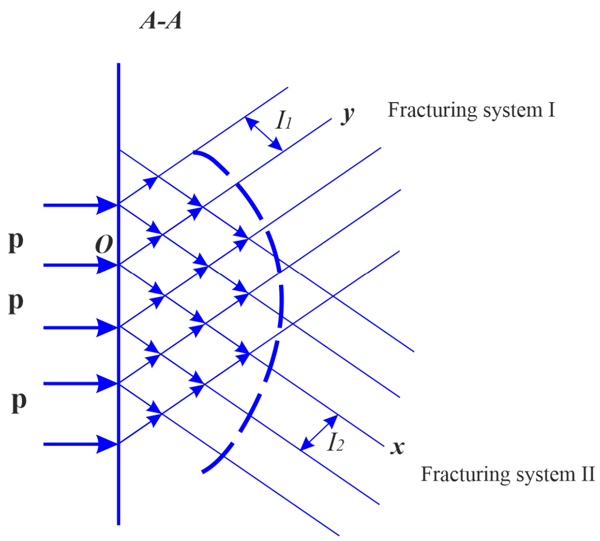

Figure 6. Formation of the contour of ore deposit strengthening within the intense fracturing zone.

The statement is based on a dynamic coefficient of viscosity that depends on a velocity gradient and has nonlinear dependence between the displacement velocity at each point of the rheological curve and a velocity gradient:

$$\frac{dv}{dy} = f(\tau).$$

The backfill mixture is in a liquid state provided that, being applied, tangential stresses are more than τ_0. Their plastic viscosity is represented by a constant of Bingham fluid in the form of

$$\eta = (\tau - \tau_0)/\dot{\gamma}$$

where $\dot{\gamma}$ is displacement velocity and τ_0 is boundary shearing stress.

Similar to a Newtonian liquid, value η does not depend on the location of the components of a stress tensor and a deformation rate.

The backfill mixtures of the mined-out spaces of stopes can be considered as ideal viscoelastic bodies that, being at rest, have spatial structural configuration and are rather stiff to resist any stresses not exceeding τ_0 value. Exceedance of a liquid limit results in the complete destruction of the structure. A system starts behaving as a usual Newtonian liquid at shearing stresses $\tau \gg \tau_0$. The structure recovers under conditions where the acting shearing stresses are less than τ_0.

To form a solid artificial massif, the mined-out space of a stope is filled gradually to height h. The depth of the backfill mixture penetration into the intense fracturing zone is determined by hydrostatic pressure that is formed by filling height h_1. Each point of the contour of the backfill mixture distribution can relate to point 0 on the stope wall.

Thus, a network of broken sections of l_1 and l_2 length is formed, where pressure in the horizontal plane across the width of the intense fracturing zone will be similar. Assume that local pressure loss due to the friction of the backfill mixture against the fracture surfaces is not considered, and there is no hydrostatic pressure of ground water at the level of artificial massif formation, and the pressure on the height of the intense fracturing zone is h_1. The shortest way of the mixture flowing consists of n_1 sections of the fractures of system I with opening δ_1 and fractures n_2 of system II with opening δ_2 which are the basis of determining pressure from the pitch height of the artificial massif formation by the equation

$$\Delta P_1 \, n_1 + \Delta P_2 n_2 = P_{\text{н}} \quad (1)$$

where ΔP_1 is pressure loss while the backfill mixture flows within the section of a fracture with opening δ_1; ΔP_2 is pressure loss while the backfill mixture flows within the section of a fracture with opening δ_2; $P_н = gph_1$ is pressure formed from the pitch height of the artificial massif formation; and n_1 and n_2 are the numbers of the fracture sections with openings δ_1 and δ_2 filled with the backfill mixture.

Consider that not all sections of the systems within the intense fracturing zone will be filled completely with the backfill mixture with opening, and their numbers will be, respectively,

$$n_1 \frac{x}{l_1}; n_2 \frac{y}{l_2}$$

where x, y are coordinates of the fixed point on the ore mass contour in terms of direction of the backfill mixture flowing within the horizontal plane in the intense fracturing zone.

Having substituted discontinuity values of the section into Equation (1), we will find:

$$\Delta P_1 \, n_1 \frac{x}{l_1} + \Delta P_2 n_2 \frac{y}{l_2} = P_н = const. \quad (2)$$

This means that the pressure difference for all points outgoing from point 0 is similar for all the shortest ways of filling the intense fracturing zones. Equation (2) is the equation of a straight line for the direction of backfill mixture distribution under pressure $P_н = gph_1$; it is of rhomboid shape at each moment of the filling of the mined-out space of a stope.

The backfill mixture has solid components of rock (20 mm) and metallurgical slag (0.074) that will prevent the penetration of the plastic-phase liquid into fractures. As for determining the loss of pressure $P_в$ for overcoming the resistance of liquid viscosity, apply the Poiseuille equation:

$$\Delta P_в = \frac{12\eta l q}{\delta^3} \quad (3)$$

where η is the dynamic coefficient of viscosity of the backfill mixture and q is the consumption of the backfill mixture in a fracture.

Pressure difference $\Delta P_{пл}$ is consumed for overcoming the plastic properties of the backfill mixture:

$$\Delta P_{пл} = \frac{2l\tau_0}{\delta} \quad (4)$$

The length of the fracture filling within a horizontal plane of intense fracturing will be in terms of $\Delta P_{пл} \gg \Delta P_в$ and the fracture opening, as well as the dynamic shearing stresses of the fracture under filling.

The value of the backfill fracture penetration into the ore mass depends on the pressure $P_н = gph_1$, the granulometric composition of the solid filling material, and a value of the fracture opening. The pressure within the intense fracturing zone is a variable value as the mined-out space is filled gradually in terms of varying filtration properties.

Under conditions of inhomogeneity of the backfill mixture components, the radius R of the backfill mixture penetration into the ore deposit for its further stable form in the fractured medium is determine by the equation:

$$R = (\alpha\delta(gph_1 - p_\tau)/2p_\tau \pm \delta\gamma sin\alpha); \quad (5)$$

where α is the inclination angle of a fracture to the lateral line of the mined-out space; γ is the specific weight of the backfill mixture; and p_τ is the plastic strength of the viscoplastic backfill mixture.

Changes in the ellipsoid curve will depend on the inclination angle of a constantly open fracture at sign "+" along the radius upward downdip (system I); sign "−" is downwards.

4.4. Scientific and Practical Results while Forming an Artificial Massif within the Intense Fracturing Zone

A scientific problem of the stability control of a natural and artificial massif formed in the mined-out space in terms of considerable outcropping area is in the difference between them due to technological features as well as different intensities and openings of fracturing systems of the ore deposit in the walls of the mined-out space.

The determination of this scientific problem is connected with the functioning of complex technological schemes of filling the natural rock mass fracture depending on its location relative to the height of filling of the mined-out space with the backfill mixtures. That requires theoretical studies and specifications of the main regularities of artificial massif formation in a fracture at its different angles of location.

The idea of the study is to apply a theory of Newtonian liquid to consider a process of artificial massif formation based on the plastic properties of the particles of filling material in the backfill mixture that corresponds to a similar Coulomb friction.

The main scientific statement is the formation of a stable state of an artificial massif within the intense fracturing zones of the ore deposit, based on the preventive control of the processes for developing a structure of backfill mixtures for fracture filling relying on the laws of Newtonian liquid. As a result, the authors have obtained important findings from the studies:

- For the first time, it has been substantiated that the available fracturing of rock and ore masses and their zones of intense manifestations influence the control for an artificial massif in the mined-out space of stopes;
- The dependence of the strength formation within the artificial massif contact on the fracture location, its opening in the rock mass and the granulometric composition of a filling material of the backfill mixture are determined;
- For the first time, the penetration of the backfill mixture into the fractures of the intense fracture-formation zones and the development of contact stresses in the artificial massif have been substantiated.

5. Conclusions

The stable state of the artificial backfilled rock of the ore deposit on the basis of preventive management in creating the structure filling cracks, based on the laws of Newtonian fluid, has been achieved. This allows the maintenance of the integrity of the rock mass, and the creation of safe conditions of mining. The use of the mining system with the backfilling of the goaf in the Pivdenno-Belozerske deposit made solving the problem of the rich ore mining under the Buchak aquifer and the preservation of agricultural earth surface possible. During research, the following results were established:

1. The main exogenous systems of fracturing in the "Holovna" ore deposit are systems with dip azimuths of 260–275°, 10–15° and 30–35°, as well as 80–85°, which are manifested in the form of zones with very low and low resistance;
2. The mineral composition of finely dispersed components of the backfilling mixture was studied and it was found that the minerals of blast furnace granulated slag-melilite and pseudo-wollastonite, and flux waste-calcite and dolomite, are part of the hydration process. These minerals, in the composition of the mixture, are able to penetrate into the open cracks of the rock mass;
3. The ratio of the opening of the crack to the granulometric composition of the backfilling mixture, which allows the penetration into the rock mass, has been established;
4. A calculation scheme and analytical equations have been developed to determine the parameters of the penetration of the backfilling mixture into the zone of intersection of intense fissuring in the rock mass;
5. The existing technology of forming a hardening layer does not provide tamponade of the microcracks in the rock mass;

6. The presence of a plug in the ore mass in the flat form of a parallelepiped has been proven, which confirms the statement that the backfilling mixture penetrates only to the open crack of the intersection zone of intense fracturing.

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