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# IMPROVING THE QUALITY OF BACKFILL MIXTURES BY ADDING PLASTICIZERS

**Purpose.** To determine the impact of plasticizers on the rheological properties of backfill mixtures, specifically their flowability and strength, to improve the efficiency of backfill operations in underground ore mining.

**Methodology.** The backfill mixture was formulated according to the project for ore mining at the Maykain field. M400 Portland cement, flotation tailings, and water were used in the research. Experimental studies were conducted on cubic samples with dimensions of 100 × 100 × 100 mm, prepared with the addition of Pozzolith MR 55, NEOLIT-203, and NEOLIT-206 plasticizers in quantities of 0.5, 1.0, and 1.5 kg/m$^3$. Flowability (cone slump method) and strength (compression tests at 14 and 28 days) were measured.

**Findings.** The study showed that the use of plasticizers significantly improves the flowability and strength of backfill mixtures. The maximum effect was achieved using NEOLIT-206 at a dosage of 1.0 kg/m$^3$. Flowability increased by 23.8 %, while the strength of the backfill mass increased by 14.2 % after 28 days. The use of Pozzolith MR 55 improved flowability but caused a decrease in the strength of the backfill mass.

**Originality.** For the first time, the effects of NEOLIT-203, NEOLIT-206, and Pozzolith MR 55 plasticizers on the rheological properties of backfill mixtures have been studied. Optimal dosage ratios were established to achieve a balance between flowability and strength using mining industry tailings.

**Practical value.** The results are significant for enhancing the efficiency of backfill operations in the mining industry. The use of NEOLIT-206 reduces cement consumption, improves mixture transportability, and ensures the required strength of the engineered mass.

**Keywords:** *plasticizers, backfill mixture, flowability, strength, underground mining*

**Introduction.** The prosperous existence of civilization from the moment of human origin is provided as a superstructure on the basis, the main bearing structure of which is a complex based on the use of natural mineral raw materials [1]. Time confidently dictates a continuous increase in the need for metals due to the growth of the population, its quality of life with the achievement of equal security at the level of developed countries, the creation of new types of technology with the constant increase in demand [2, 3].

Nature is unable to meet growing demands indefinitely, as the reserves of metals in the interior are objectively depleted. Proven reserves, predicted resources, possible volumes determined by the general conditions of ore formation [4] historically cannot keep pace with the needs of a modern economy of sustainable development [5]. Furthermore, strategic decision-making and project prioritization, such as those guided by modified Fuzzy Analytical Hierarchy Process approaches, can enhance resource management and sustainability in industrial sectors [6, 7].

The mining industry in Kazakhstan plays a crucial role in the country's economy, leveraging its vast mineral resources, including significant deposits of coal, copper, gold, and uranium. As one of the world's largest uranium producers and a major supplier of other metals, Kazakhstan continues to expand its mining sector to meet global demand and drive economic development, with investments in sustainable practices to balance industrial growth with environmental considerations [8].

Traditional deposits in the continental earth crust to a depth of 5 km are objectively becoming fewer and fewer [9], and the moment will come, in 30–150 years, de-

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pending on the type of metal, when there will be no such deposits, at all [10]. At the same time, losses during mining, inevitable due to the design features of the technologies used, geomechanical conditions, artificially created as a result of human intervention in the subsoil, lead to a reduction in reserves compared to those determined by geological exploration by 5–40 % or more and left in different types of pillars [11].

However, recently the most difficult and important task in the mining of mineral deposits is to eliminate the increased stress in the rock mass caused by the increased pressure of the overlying rock stratum [12]. At a certain point, these stresses can exceed the strength of the rocks, which begin to collapse, releasing significant energy. There is a dynamic rock pressure manifestation in the form of the so-called rock burst, which has a negative impact on the safety of mining operations using the underground mining method [13].

One solution to reduce ore losses, extend the depletion period of reserves and ensure the safety of mining operations is to use underground mining systems with backfilling of the mined-out space [14]. The objective advantages of mining systems with backfilling are the effective rock pressure management, high percentage of ore extraction from the subsoil, reliability of maintaining and preventing the surface from caving, increased safety of deposit mining, as well as the potential for recycling waste from mining and beneficiation production [15, 16].

The efficiency of deposit mining by backfill systems depends on the ore value, its extraction level, mine performance, and, importantly, the cost of backfilling operations especially considering use of tailings [17]. Moreover, it is the reduction in the cost of backfill mass, which is an integral part of the ore cost and is relevant for all mining enterprises. However, the use of backfilling is associated with some problems, such as difficulties in transporting solidifying mixtures (increasing the required transportation distance through a horizontal pipeline), as well as the limited time during which the mixture remains in a moving state. All this requires increased water content in the mixture – 450–550 l/m$^3$. In turn, increased water content reduces the backfill mass strength, since only 30–40 % of water comes into reaction with cement clinker (cementitious agent). The rest of the water remains in the solidified backfill mass in the form of water pores, reducing its strength.

The introduction of additives-plasticizers is one way to improve the rheological properties of backfill mixtures, such as flowability, as well as the strength characteristics of the backfill mass, which ultimately leads to a reduction in the cost of backfilling operations [18]. The main effect of using additives-plasticizers is to increase the mixture flowability while preserving the strength characteristics of concrete after settling. The use of plasticizers reduces the amount of water used to prepare the solution.

To date, a fairly large assortment of chemical additives of domestic and foreign production is used. Additives-plasticizers greatly liquefy concrete by enveloping cement and aggregate grains, creating together with water a sliding film, thereby reducing friction between solid concrete components and increasing its flowability. It also significantly increases the number of crystallization centers in the formation of cement stone, which in turn increases the strength characteristics of the resulting concrete and backfill masses when backfilling operations are conducted underground. Additionally, advanced materials research, such as the study of ceramic-metal nanostructured coatings on steels, has shown potential to improve the mechanical and damping properties of alloys used in construction and mining equipment [19].

Backfill mixtures differ significantly in their characteristics from building concrete. There is experience in using Pozzolith plasticizers, which increase the flowability and strength of the backfill mixture. However, the addition of these plasticizers to the solution results in an increase in chlorine concentration and a high cost of the backfill mixture. Therefore, we propose to use plasticizers such as NEOLIT-203 and NEOLIT-206, which provide high final concrete strength, do not contain substances that cause corrosion of reinforcement, and reduce the water consumption for concrete mixture. Additives of this type are used to produce more homogeneous mixtures. By binding to cement, they repel particles from each other due to electrostatic forces, which improves the fluidity of the solution while reducing water consumption. With less water in the mixture, the backfill mass strength during solidification is improved.

**Literature review.** Recent studies have extensively explored various aspects of mining technologies and materials, aiming to address the challenges associated with underground mining operations. For instance, research by [20] examined the impact of ground surface subsidence caused by underground coal mining on critical infrastructure, such as natural gas pipelines, emphasizing the need for effective backfill systems to mitigate these effects. Similarly, investigations into the state of rock masses in near-wall parts of quarries and their stability management, as presented in paper [21], highlight the importance of rock mass stability to ensure long-term operational safety.

The importance of material properties in mining operations is also underscored by research studies [22, 23], who studied the damping properties of alloyed steels with ceramic-metallic nanostructured coatings, demonstrating the potential of advanced materials to improve equipment durability and performance in harsh underground environments. In addition, the work [24] describe the properties of ash and slag waste illustrate the potential of such by-products as components for construction and backfill mixtures, contributing to sustainable waste management.

A number of studies have also addressed the challenges associated with ore extraction and processing. For example, in research [25], a systematic approach to improving mineral mining processes is presented, which is crucial for developing efficient mining systems. Similarly, the analysis of silicomanganese markets by [26] underscores the growing demand for innovative technologies to process mineral resources, a demand that directly influences the composition and performance of backfill mixtures.

The environmental implications of mining activities have been another area of focus. Research [27] on rare-metal mineralization in salt lakes demonstrates the linkage between environmental and geological factors, offering insights into how backfill systems can be designed

to minimize ecological impact. Furthermore, studies [28] on new technologies in sustainable mining production emphasize the integration of tailings management into operational workflows to enhance efficiency while reducing environmental risks.

Finally, specific attention has been given to innovative approaches in backfilling. The work [29] on geodetic substantiation of copper ore regions highlights the critical role of accurate geological data in designing effective backfill strategies. Similarly, the authors in research [30] explored extraction technologies for fine vein gold ores, revealing the potential for tailored backfill solutions to support such operations.

Despite the progress reflected in these studies, unresolved challenges remain. Future research should focus on integrating advanced additives, optimizing mixture compositions, and evaluating the long-term performance of backfill systems under varying conditions to address the complex demands of underground mining. The development and optimization of backfill mixtures for underground mining systems have been the focus of numerous studies in recent years. Researchers have explored various approaches to enhance the rheological and mechanical properties of backfill mixtures by incorporating chemical additives and utilizing alternative materials as filling components. For example, studies have shown that plasticizers, such as Pozzolith MR 55 and other advanced additives, significantly improve the flowability and strength of backfill mixtures, making them more suitable for underground transportation and long-term stability.

Moreover, the influence of flotation tailings as a primary component in backfill mixtures has been well-documented. Investigations into their mineralogical composition and mechanical behavior, such as the studies conducted on tailings from the Maykain field, have highlighted the importance of optimizing particle size and water content to achieve the desired performance characteristics. The use of flotation tailings has also been recognized as an environmentally sustainable practice, contributing to waste recycling and resource conservation.

Further advancements in the field have focused on understanding the impact of various additive dosages on the mechanical properties of solidified backfill masses. For instance, the use of NEOLIT-203 and NEOLIT-206 has been studied extensively, revealing their potential to reduce water consumption while maintaining or even enhancing the strength and flowability of backfill mixtures. These findings align with global trends in mining research, where the focus has shifted toward resource-efficient and sustainable backfilling solutions.

In addition, recent works have explored the economic and environmental implications of backfill systems. The integration of cost-effective additives, combined with the utilization of locally available materials, has been identified as a critical strategy for reducing operational expenses without compromising safety or performance. This is particularly relevant for mining operations in regions with challenging geotechnical conditions, such as Kazakhstan, where high-stress environments and dynamic rock pressure manifestations require robust and reliable backfill solutions.

**Unsolved aspects of the problem.** The existing studies on backfill mixtures demonstrate advancements in improving flowability and strength. However, they do not fully address the impact of different plasticizers on these properties under varying conditions. Additionally, there is limited data on the combined effects of plasticizer type, dosage, and material composition on the long-term performance of backfill mixtures. These gaps necessitate further research to optimize mixture design and adapt it to specific operational requirements.

**The purpose of this research** is to improve the rheological properties of backfill mixtures, such as flowability and strength of backfill mixtures of different ages using additives-plasticizers.

The research objectives are:

- to prepare standard samples-cubes of backfill mixtures of the present composition for laboratory experiments;
- to identify the influence of different plasticizers on the variation of the backfill mixture flowability and strength;
- based on comparison of parameters, to select the most appropriate additive for the research object conditions.

**Materials and methods.** To determine the influence of the proposed plasticizers on the main characteristics of the solidifying backfill mixtures, they are compared with the results of previously conducted studies using Pozzolith MR 55 plasticizer, as well as with the backfill mixture composition used in the Maykain field, that is, without adding a plasticizer.

The backfill mixture composition is adopted according to the project for mining the Maykain field using underground mining systems with backfilling, where M400 Portland cement is used as a cementitious agent, and flotation tailings from the tailing dumps were used as filling material: cement – 130, tailings – 1,389, water – 439, mixture density – 1,835–1,889 kg/m$^3$.

Flotation tailings from the Maykain concentrating plant were used as filling materials. Preliminary X-ray phase analysis showed a predominance in the mineralogical sample composition of quartz compounds – 28.1 %, barite – 22.3 %, as well as the presence of sulphide minerals: pyrite – 7.1 % and zinc sulphide – 6.1 %. Maykain concentrating plant is part of the Maykainzoloto JSC, which is located in the Pavlodar Region of the Republic of Kazakhstan. Maykainzoloto JSC is one of the leading enterprises in the mining and processing of gold-bearing pyrite-polymetallic ores in Central Kazakhstan. Accidents related to caving of the ceiling that occurred at the mine made it difficult to complete mining of under-open-pit and near-wall ore reserves. In addition, this has led to disruption of the underground mine ventilation, seepage of open-pit water and water from various atmospheric precipitations. All this ultimately has led to complications in ore mining and its increased costs. Therefore, it was decided at this enterprise to switch to an underground mining system with backfilling of mined-out space. However, when designing the backfill complex, the difficulties of transporting solidifying backfill mixtures along horizontal sections of the backfill pipeline, as well as limited time during which the mixture is in a moving state, were not sufficiently taken into account.

To determine the influence of additives on the flowability and strength of the backfill mixture and to obtain

*Table*

Experimental studies of screening with direct sieve excitation

| Technical characteristics | Pozzolith MR 55 | NEOLIT-203 | NEOLIT-206 |
|---|---|---|---|
| Additive type | Dry | Dry | Dry |
| Color | From light brown to dark brown | Brown | Brown |
| Density, kg/m$^3$ | 1,150–1,190 | 800 ± 50 | 900 ± 50 |
| Level of pH | 5 ± 2 | 7–9 | 7–9 |
| Cl-1 content, % | Not more than 0.1 | Not more than 0.1 | Not more than 0.1 |
| Manufacturer recommended additive consumption for concrete | 0.6 % or more by mass of cementitious agent | 0.2–0.7 % of dry additive by mass of cementitious agent | 0.7–1.0 % by mass of cementitious agent |
| Chemical composition | Naphthalenesulfonic acid-formaldehyde-condensation resin, chlorine accelerator | Sodium sulphate, melamine-formaldehyde-sulphite-condensation resin, chlorine accelerator | Sodium sulphate, sulphonated polycondensates, chlorine accelerator |

comparative data, when conducting laboratory experiments, the amount of each plasticizer in the mixture is changed – 0.5; 1.0 and 1.5 kg/m$^3$. The experimental results are compared with the backfill mixture without additives. Technical characteristics of plasticizers are given in Table.

Table presents key differences in their physical and chemical properties, which directly influence their performance in backfill applications. All three plasticizers are dry additives, making them easy to store and transport. The density of NEOLIT-203 and NEOLIT-206 is significantly lower than that of Pozzolith MR 55, which may contribute to their lower dosage requirements and reduced material costs. The pH levels of NEOLIT-203 and NEOLIT-206 indicate that these additives are more neutral compared to Pozzolith MR 55, which is slightly acidic. This neutral pH may reduce the risk of adverse chemical reactions with cementitious materials, contributing to improved mixture stability.

All three additives have a low chlorine content, which minimizes the risk of corrosion in reinforced concrete structures, making them suitable for underground mining applications where long-term durability is critical. The recommended dosage of NEOLIT-203 is the lowest among the three, followed by NEOLIT-206 and Pozzolith MR 55. The lower dosage requirements of NEOLIT-203 suggest higher efficiency and cost-effectiveness, particularly for large-scale applications. The chemical composition of these additives highlights their functional differences. Pozzolith MR 55 contains naphthalenesulfonic acid-formaldehyde-condensation resin, which acts as a chlorine accelerator. In contrast, NEOLIT-203 and NEOLIT-206 utilize sodium sulphate-based components, including sulphonated polycondensates and melamine-formaldehyde-sulphite-condensation resins. These compositions are tailored to improve flowability while maintaining the strength of solidified backfill mixtures.

The distinct characteristics of these plasticizers influence their suitability for different conditions. Pozzolith MR 55, while effective, requires higher consumption and is slightly acidic, which may limit its efficiency in specific applications. NEOLIT-203 and NEOLIT-206, with their lower consumption rates and neutral pH levels, appear more suitable for enhancing the flowability and strength of backfill mixtures while reducing water consumption and material costs. The flowability and strength of the backfill mixture are examined as the research criteria for rheological characteristics objectively describing the state of the backfill mixture and the solidifying backfill. When producing mixtures in laboratory conditions, flotation tailings are additionally crushed in a jaw crusher to a grain size of 5 mm.

The backfill mass properties are determined by preparing and testing standard samples-cubes of backfill mixtures of the present composition. The samples are manufactured in demountable molds with a polished inner surface. The molds are sufficiently rigid, not deformed during the formation of the samples. This makes it possible to exclude the loss of cement milk during the formation of samples. The size of the cubic molds for backfill mixtures is 100 × 100 × 100 mm (Fig. 1).

After compaction, samples in molds, covered with a damp cloth, are stored at a temperature of 16–20 °C for 3 days. Then they are removed from the molds, labeled and, until testing, stored at a temperature of 20 ± 2 °C with a relative humidity of at least 90 in sawdust, watered regularly.

The backfill mixture flowability without coarse aggregate is determined by a standard cone slump. A cone

*Fig. 1. Molds filled with a mixture*

with a height of 150 mm, an apex angle of 30° and a base diameter of 75 mm has a mass of 300 ± 2 g. The vessel in which the test mixture is placed has the shape of a truncated cone. The vessel height is 180 mm, and the base diameter is 150 mm.

The test mixture is packed into a vessel and compacted with a bayonet (25 times) with a steel rod 10–12 mm in diameter, then shaken 5–6 times, lightly tapping it on the table. The vessel is mounted on a stand, and the cone tip is brought into contact with the mixture surface. Then, the bar is lowered until it comes into contact with the cone rod and is set against the zero arrow of the dial. By pressing a spring button, the cone is released and freely immersed in the backfill mixture. After 10 seconds, the bar is lowered until it comes into contact with the cone rod and the immersion depth is determined with an accuracy of 0.2 cm. The flowability value is determined as the arithmetic mean of two tests.

The backfill mass strength is determined in the laboratory by testing samples-cubes by crushing them on a hydraulic press at the age of 14 and 28 days according to GOST 10180-90. For testing, the samples are set on the press support plate centrally relative to its axis.

The load increases at a constant rate of 0.6 ± 0.2 MPa per second until the sample is destroyed. The maximum load value is taken as the de-stressing value.

**Results and discussion.** This section provides the results of laboratory experiments conducted with the present mixture composition when introducing plasticizers in an amount of 0.5, 1.0 and 1.5 kg/m$^3$: cement – 130, tailings – 1,389, water – 439, mixture density – 1,835–1,889 kg/m$^3$.

As a result of processing laboratory experiment data on the influence of the amount of additives ($D$) on the backfill mixture flowability ($b$), graphical interpretations have been obtained (Fig. 2).

Analysis of the laboratory experiment results shows that with the present backfill mixture composition without adding a plasticizer, the flowability value is 10.7 cm. When adding NEOLIT-203 plasticizer into the mixture composition in an amount from 0.5 to 1.5 kg/m$^3$, a sharp increase in the backfill mixture flowability from 10.7 to 11.3 cm is initially observed. A further increase in the amount of plasticizer results in a slight increase to 11.7 cm. The same pattern of flowability dependence is observed when adding Pozzolith MR 55 plasticizer. When introducing Pozzolith MR 55 plasticizer in an amount of 0.5 kg/m$^3$, flowability increases from 10.7 to 12.0 cm, and with an amount of 1.5 kg/m$^3$, the flowability value reaches a maximum of 12.5 cm.

When adding NEOLIT-206 plasticizer into the mixture composition in an amount from 0.5 to 1.5 kg/m$^3$, a slight increase in the backfill mixture flowability from 10.7 to 11.7 cm is initially observed. A further increase in the amount of plasticizer to 1.0 kg/m$^3$ results in a maximum increase in flowability to 13.3 cm. The increase in the amount of plasticizer to 1.5 kg/m$^3$ results, on the contrary, in reducing the backfill mixture flowability to 12.9 cm.

When NEOLIT-203 plasticizer is added to the backfill mixture from 0.5 to 1.5 kg/m$^3$, the flowability value gradually increases from 5.6 to 9.3 % compared to the mixture without the additive. The same pattern of flowability dependence is observed when adding Pozzolith MR 55 plasticizer. When introducing NEOLIT-206 plasticizer, the increase in flowability varies from 9.4 to 23 %. Moreover, the maximum increase is achieved when the amount of added plasticizer is 1.0 kg/m$^3$.

The experimental data presented show that the introduction of additives-plasticizers into the backfill mixture increases its flowability, and the introduction of NEOLIT-206 achieves maximum backfill mixture flowability, which should have a positive effect on the transportability of the mixture as a whole.

Fig. 3 shows the increase in the backfill mixture flowability in percent ($b_g$) when introducing various plasticizers and different amounts of additives ($D$) compared to the backfill mixture without a plasticizer.

Increasing the flowability of the solidifying backfill mixture by introducing chemical additives into it makes it possible to reduce the water content of the mixture, and this in turn should lead to an increase in the solidified backfill mass strength. Therefore, to determine the influence of plasticizers added into the backfill mixture on its strength, backfilled cubes are tested at the age of 14 and 28 days by crushing them on a hydraulic press. The results of experiments with cubes aged 14 days are graphically presented in Fig. 4.

Accordingly with the present backfill mixture composition without adding a plasticizer, the strength value

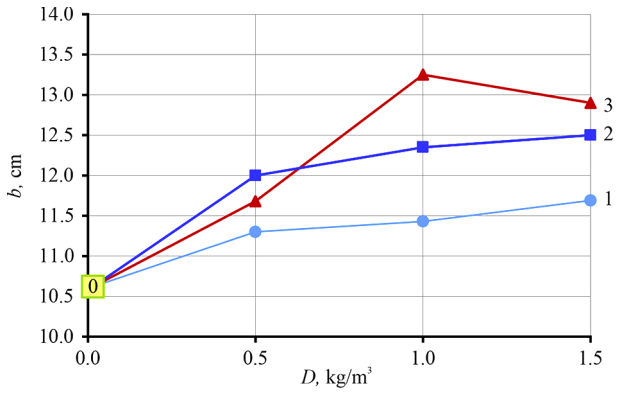


*Fig. 2. Changes in backfill mixture flowability (b) using additives-plasticizers (D):*

*1 – using NEOLIT-203 additive-plasticizer; 2 – using NEOLIT-206 additive-plasticizer; 3 – using Pozzolith MR 55 additive-plasticizer*

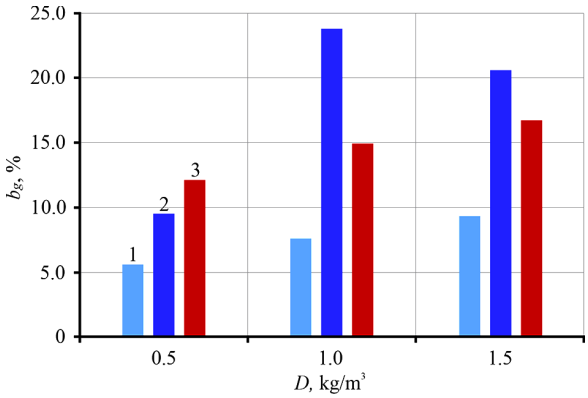


*Fig. 3. Increase in the mixture flowability when using additives-plasticizers:*

*1 – using NEOLIT-203 additive-plasticizer; 2 – using NEOLIT-206 additive-plasticizer; 3 – using Pozzolith MR 55 additive-plasticizer*

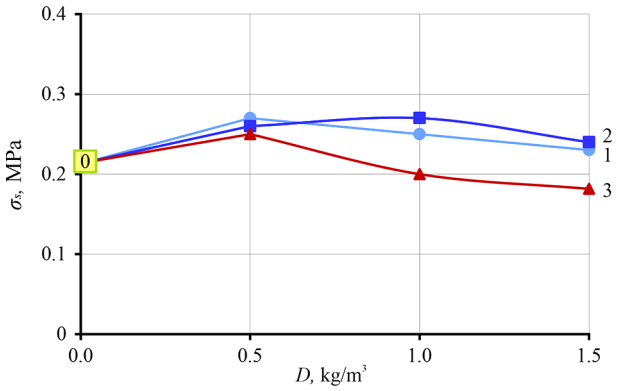


*Fig. 4. Changes in the strength ($\sigma_s$) of backfill mixture samples depending on the amount of additives-plasticizers (D) at the age of 14 days:*

*0 – no additives used; 1 – using NEOLIT-203 additive-plasticizer; 2 – using NEOLIT-206 additive-plasticizer; 3 – using Pozzolith MR 55 additive-plasticizer*

is 0.21 MPa. When adding NEOLIT-203 plasticizer into the mixture in an amount from 0.5 to 1.5 kg/m$^3$, a sharp increase in the backfill mixture strength from 0.21 to 0.27 MPa is initially observed. A further increase in the amount of plasticizer results in a gradual decrease in the backfill mass strength to 0.23 MPa. The same pattern of strength dependence is observed when adding NEOLIT-206 plasticizer. When introducing plasticizer in an amount of 0.5 kg/m$^3$, strength increases from 0.21 to 0.23 MPa, and with an amount of 1.0 kg/m$^3$, the strength value reaches a maximum of 0.27 MPa, and then decreases to 0.24 MPa. When introducing Pozzolith MR 55 plasticizer in an amount of 0.5 kg/m$^3$, the backfill mixture strength increases to 0.25 MPa, and with an increase in the amount of plasticizer to 1.5 kg/m$^3$, strength decreases to 0.18 MPa. In general, when conducting an experiment with cubes aged 14 days, the maximum strength is achieved by introducing NEOLIT-206 plasticizer into the backfill mixture.

If in previous experiments, with the introduction of Pozzolith MR 55 plasticizer in an amount of 1.0 kg/m$^3$, the backfill mixture strength increases by 19 %, then with the introduction of NEOLIT-206 plasticizer, the strength increases by 28.6 %. Thus, relative increase is by 9.6 %.

Similar experiments to determine the strength of the present backfill mixture compositions at the age of 28 days and the introduction of plasticizers make it possible to obtain changes in the strength of the samples (Fig. 5).

Fig. 5 shows that with the present backfill mixture composition without adding a plasticizer, the strength value is 0.67 MPa. When adding NEOLIT-203 plasticizer into the mixture composition in an amount from 0.5 to 1.5 kg/m$^3$, a sharp increase in the backfill mass strength from 0.67 to 0.71 MPa is initially observed. A further increase in the amount of plasticizer first leads to a gradual decrease in the backfill mass strength to 0.68 MPa, then to an increase to 0.72 MPa. When introducing NEOLIT-206 plasticizer in an amount from 0.5 to 1.5 kg/m$^3$, a gradual increase in the backfill mass strength from 0.67 to 0.76 MPa is observed. When introducing Pozzolith MR 55 plasticizer in an amount of 0.5 kg/m$^3$, an increase in the backfill mixture strength is first observed to 0.68 MPa, and then an increase in the amount of plasticizer to 1.5 kg/m$^3$ leads to a sharp decrease in strength to 0.39 MPa. Thus, the backfill mixture strength is less than that of mixture without plasticizer. Increase in the amount of Pozzolith MR 55 plasticizer from 1.0 to 1.5 kg/m$^3$ both on the *14$^{th}$* and *28$^{th}$* days of the cube's age leads to a decrease in the backfill mixture strength.

Fig. 6 shows the parameters for changing the backfill mixture strength in percent ($b_s$) with the introduction of various plasticizers and different amounts of additives ($D$) compared to the backfill mixture without a plasticizer.

Fig. 6 shows that the increase in the backfill mass strength when introducing NEOLIT-203 plasticizer from 0.5 to 1.5 kg/m$^3$ is 1.5–8.2 %, while the minimum increase is observed with the amount of plasticizer from 1.0 kg/m$^3$, and the maximum increase is at 1.5 kg/m$^3$. When introducing Pozzolith MR 55 plasticizer in an amount of 0.5 kg/m$^3$, a slight increase in strength by 2.3 % is observed. A further increase in the amount of plasticizer, on the contrary, leads to a decrease in the backfill mixture strength by 16.4 and 41.8 % compared

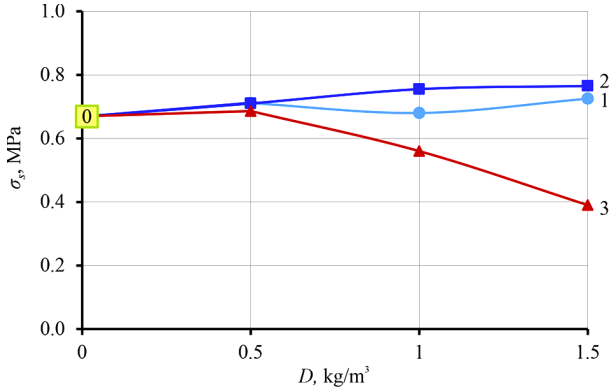


*Fig. 5. Changes in the strength ($\sigma_s$) of backfill mixture samples depending on the amount of additives-plasticizers ($D$) at the age of 28 days:*

*0 – no additives used; 1 – using NEOLIT-203 additive-plasticizer; 2 – using NEOLIT-206 additive-plasticizer; 3 – using Pozzolith MR 55 additive-plasticizer*

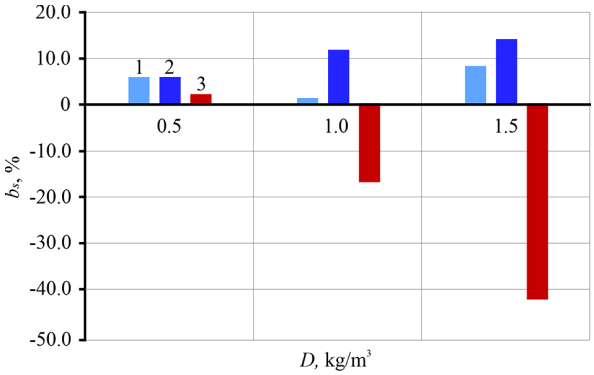


*Fig. 6. Changes in the strength of backfill mass samples when using additives-plasticizers with the present mixture composition at the age of 28 days:*

*1 – using NEOLIT-203 additive-plasticizer; 2 – using NEOLIT-206 additive-plasticizer; 3 – using Pozzolith MR 55 additive-plasticizer*

to the present backfill mass composition without adding a plasticizer. The best strength parameters are observed when introducing NEOLIT-206 plasticizer. It should be noted that when introducing an additive in an amount of 0.5 kg/m$^3$, the increase in strength is 6.0 %, and at 1.5 kg/m$^3$ it is 14.2 %. In general, when conducting research with cubes aged 28 days, the maximum strength is achieved by introducing NEOLIT-206 plasticizer into the backfill mixture. By increasing the mixture flowability, when introducing additives-plasticizer into its composition, the strength of the backfill mass samples also increases.

Thus, we have revealed that the chemical additive NEOLIT-206 is the most suitable for backfill materials proposed for use at the Maykain field. The use of this additive in the backfill mixture composition makes it possible (depending on the additive dosage) to increase the flowability of the mixture in laboratory conditions from 9.4 to 23.8 %, as well as to increase the strength of the backfill mass aged 28 days from 6.0 to 14.2 %. All this ultimately makes it possible to increase the backfill mixture flowability and reduce the expensive cement consumption, provided that the backfill mass strength is maintained.

The Maykain field has been mined for more than 80 years, first by open-pit and then by underground methods. Therefore, there are sufficient volumes of rocks from tunneling operations and overburden dumps, as well as screenings from crushing-screening plant, which can be used as aggregates. The grains of these aggregates have a predominantly platy shape and change their granulometry and shape during the backfill mixture preparation. Thus, further research is needed to determine the backfill mixture quality when using these additives. The proposed additive can be used in the preparation of backfill mixtures during mining of under-open-pit and near-wall ore reserves in the Maykain field by staged mining and backfilling using backfill mixtures of various rheological characteristics that correspond to the conditions of their stable pipeline transportation and provide the required strength.

**Conclusions.** The underground mining method is related to the problems of managing the state of the mined-out masses, the completeness of the subsoil use, the risk of a broken ore fire, as well as to ensuring safe working conditions. Backfilling of the mined-out space with artificial masses of available materials allows solving these problems. However, the high cost and complexity of transporting the backfill mixture to mined-out blocks limit its use. The paper presents the experimental research results on the introduction of additives-plasticizer into the backfill mixture, which will reduce cement consumption without reducing the backfill mass strength, while simultaneously increasing its flowability.

From the conducted analysis of the influence of chemical additives-plasticizer on the rheological properties of the backfill mixture, it can be concluded that the introduction of additives-plasticizer into the present backfill mixture composition can improve its flowability and strength, which accordingly increases the distance of backfill mixture transportation and reduces the number of emergency situations.

When adding Pozzolith MR 55 plasticizer in an amount of 0.5 kg/m$^3$, the maximum flowability value of the backfill mixture is achieved; however, the backfill mass strength is lower than when using other types of plasticizers.

By comparing the flowability and strength values of the backfill mixture, it has been proven that their maximum values are achieved when adding NEOLIT-206 additive-plasticizer in an amount of 1.0 kg/m$^3$ into the present backfill mixture composition directly at the research site. An increase in the mixture flowability by 23.8 % and the backfill mass strength by 14.2 % at the age of 28 days, respectively, will reduce the cementitious agent consumption by the same amount, provided that the required design strength of 0.67 MPa is maintained. So, the efficient use of plasticizers can reduce material consumption, increase the safety and efficiency of transporting backfill mixtures.

While this study has demonstrated significant improvements in the flowability and strength of backfill mixtures using NEOLIT-203 and NEOLIT-206 plasticizers, several critical issues remain unresolved. These gaps highlight areas that require further investigation to fully address the challenges associated with underground mining backfill systems.

Firstly, the interaction between the mineralogical composition of flotation tailings and the introduced plasticizers requires further exploration. Although preliminary analysis revealed the predominance of quartz, barite, and sulphide minerals in the tailings, their specific impact on the backfill mixture's long-term chemical stability and mechanical properties has not been systematically studied. This is especially critical for conditions in the Maykain field, where unique geological factors may affect the behavior of the backfill mass.

Secondly, the influence of particle size distribution of tailings on the flowability and strength of backfill mixtures has not been fully addressed. While this study used tailings crushed to a standard size, optimizing particle size distribution could further enhance the rheological properties and transportability of the mixtures over long pipeline distances.

Thirdly, the scalability of laboratory findings to field-scale applications remains a pressing issue. The challenges of transporting backfill mixtures over extended distances in underground conditions, where changes in temperature, pressure, and pipeline geometry can affect the mixture's properties, are not yet fully understood. Field trials are necessary to validate the laboratory results and adapt the mixture composition for practical use.

Another unresolved issue is the cost optimization of backfill systems. While using NEOLIT-206 plasticizer demonstrated reduced water and cement consumption, a comprehensive economic analysis considering material costs, transportation efficiency, and long-term performance is required to substantiate the cost-effectiveness of the proposed mixtures. While the plasticizers studied do not contain chlorine or other highly reactive substances, their long-term interaction with underground water and the surrounding environment must be evaluated to ensure sustainable mining practices.

Future research will address these gaps by conducting comprehensive field trials, optimizing tailings processing, and developing detailed economic and environmental assessments. These steps are necessary to ensure

the widespread adoption of advanced backfill technologies in underground mining operations.

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## Покращення якості закладних сумішей шляхом додавання пластифікаторів

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**Мета.** Визначення впливу пластифікаторів на реологічні властивості закладних сумішей, зокрема на їх плинність і міцність, для підвищення ефективності закладних робіт при підземному видобутку руди.

**Методика.** Закладна суміш була сформована відповідно до проєкту видобутку руд на Майкаїнському родовищі. При дослідженні використовувався цемент марки М400, хвости процесу флотації та вода. Експериментальні дослідження проводилися на кубічних зразках розмірами 100 × × 100 × 100 мм, виготовлених із додаванням пластифікаторів Pozzolith MR 55, NEOLIT-203 і NEOLIT-206 у кількостях 0,5; 1,0 та 1,5 кг/м$^3$. Вимірювалися плинність (метод осадки конуса) і міцність (випробування на стиск через 14 і 28 днів).

**Результати.** Дослідження показало, що використання пластифікаторів значно покращує плинність і міцність закладних сумішей. Максимального ефекту досягнуто при використанні NEOLIT-206 у дозуванні 1,0 кг/м$^3$. Плинність зросла на 23,8 %, а міцність закладного масиву через 28 днів – зросла на 14,2 %. Використання Pozzolith MR 55 забезпечило збільшення плинності, однак спричиняло зниження міцності закладного масиву.

**Наукова новизна.** Уперше досліджено вплив пластифікаторів NEOLIT-203, NEOLIT-206 і Pozzolith MR 55 на реологічні властивості закладних сумішей. Встановлені оптимальні співвідношення дозування для досягнення балансу між плинністю й міцністю з використанням хвостів гірничого виробництва.

**Практична значимість.** Результати дослідження мають важливе значення для покращення ефективності закладних робіт у гірничій промисловості. Використання NEOLIT-206 дозволяє зменшити витрати цементу, підвищити транспортованість суміші й забезпечити необхідну міцність техногенного масиву.

**Ключові слова:** *пластифікатори, закладна суміш, плинність, міцність, підземний видобуток*

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