Backfilling for mines

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Abstract. The article introduces results of studying the problem areas in filling masses of iron ore mining-and-processing enterprise. Some basic study of back filling after the blast hole drilling has been conducted by the authors. The samples picked from the disrupted back filling have been studied for strength. The analysis of the results evidences that all the samples meet the requirements of the strength class but there is a variation of the strength characteristics which evidences about the massif inhomogenuity. The results of chemical, X-ray and fluorescent analyses proved high inhomogenuity of solidified back filling masses in the massif. The microstructure of the back filling samples has inhomogeneous structure, with a great number of various pores. A set of studies showed lack of uniformity and consolidation of the filling solution. It resulted in the loss of strength and durability of the back filling area. The analysis of possible reasons for negative results has been given. The activities to improve the quality and durability of the back filling for mines have been suggested.

1. Introduction
Development of iron ore deposits and ore mining is a topical, prospective and expensive trend in mining works. This field encounters several problems: work labour input and arduous working conditions, environmental issues, insufficient study of the soil layers, obsolescence and physical deterioration of the facilities and others. Among these issues one of the most important is the quality of the back filling which must meet the required technological, strength, non-rigid, and physical characteristics. Low quality back filling can result in land fall in mines [1, 2]. Thus, improving the quality of the back filling is a topical issue at the mining-and-processing enterprises [3–7]. The quality of the back filling determines the possibility of further ore development, working conditions, ecological safety and others. A “dot” is used as a parting agent between the fractional and a whole part both in figures and tables.

2. Main body
Iron ore deposits development and ore mining is a topical prospective and an expensive trend in mining works. This field encounters several problems: work labour input and arduous working conditions, environmental issues, insufficient study of the soil layers, obsolescence and physical deterioration of the facilities and others. Among these issues one of the most important is the quality of the back filling which must meet the required technological, strength, non-rigid, and physical
characteristics. Low quality back filling can result in land fall in mines [1, 2]. Thus, improving the quality of the back filling is a topical issue at the mining-and-processing enterprises [3–7]. The quality of the back filling determines the possibility of ore further development, working conditions, ecological safety and others. The article introduces results of studying the problem areas in filling masses of iron ore mining-and-processing enterprise. Some basic study of back filling after the blast hole drilling has been conducted by the authors.

Analysis of the back filling massif shows that all the samples have various external characteristics and peculiarities. First of all the strength of samples is different: some disintegrate by fingering others are rather strong. Sample humidity is different: from dry to wet. Great variety of the sample colors evidences poor quality of the back filling and internal strength in the massif layers. Figure 1 shows the photos of mine backfilling, different in colors and structure uniformity of the filling mass.

![Figure 1. Mine backfill](image)

To determine the strength of the filling massif samples from different areas were taken 7 x 7 x 7 cm in size from the parts fallen from the filling massif. Split off lumps were 2–4 m³ in volume, inhomogeneous in composition, which is seen as stripes of different color and strength, stripe thickness is 20–30 cm. Blocks were cut off from massifs 150 x 150 x 200 mm in size. Cubes were cut off from blocks, and the crushing strength limit for cubes has been determined. The conditionally determined type by the compressive strength varies within M21 to M100.

As a result of statistical treatment of the received values of strength the characteristic strength of the split lumps is 4.83 MPa, standard deviation $S=1.41$; variation coefficient $V=0.29$.

Samples were taken from the three lumps of the same massif. Such a variation in strength values and colors evidences undermixing the solution for the back filling, drawbacks in solution preparation, and transportation and mixture placing. The issues of quality and compatibility of the primary components for the mixture are studied separately [5, 8].

Besides, there were lustrous grains in samples, probably from the ore body. In order to study changes in properties of the mortar stone throughout the back filling massif samples were analyzed with the X-ray fluorescent spectrometer of ARL 9900 WorkStation series with in-built diffraction system.

The results of the chemical analysis allow determining indirectly the initial content of the Portland cement by the content of CaO in the original filling mixture. However, the CaO content in samples varies from 7.11 to 19.5 %, which makes variation nearly 3 times resulting in the inner massif lamination, unequal strength, internal stresses and further destruction.

The mineralogical composition of the representative sampling of the filling solution from the back filling has been studied. The equipment is DRON-2. Study parameters are: anode – Cu, step=0.05; $E_{\text{anod}}=0.38$; Speed=speed – 2; Maximum number of impacts=4630; $S_{\text{pack}}=4061$; $S_{\text{total}}=14674$; $K=27.7\%$. Figure 2 shows the X-ray fragments of the back filling samples.

X-ray phase analysis of the solution showed that it contains cement hydration products: Portlandite Ca(OH)$_2$ (dÅ = 4.94; 2.978; 2.63; 1.708) and hydrated calcium silicates C-S-H(dÅ = 2.978; 2.784;
2.63; 2.188). Besides, there is a stage of silicone dioxide SiO₂ (dÅ = 4.26; 3.35), introduced into the system by quartzy sand.

![Figure 2. X-ray fragment of the filling mixture sample](image)

It should be noted that the consolidated filling mixture has no diffraction maximums peculiar for concrete minerals which evidences about full cement hydration in the mixture. It is noted that the environment where the filling solidifies creates the best conditions: high humidity and constant temperature higher than 20 °C.

Thus, basing on the studied mineral composition of the samples of solidified filling a conclusion can be drawn that in filling massifs there are perfect conditions for concretion: high humidity and constant temperature higher than 20 °C that provides forming a solid, steady, durable massif. However, strength parameters of the filling mass first depend on a preliminary created mixture composition depending on the required designed strength.

Mechanical properties of the filling mass at a similar chemical and phase composition can alter depending on different geometrical parameters of new formations and pores, which characterize the structure of the solidified material [8-10]. To receive high-endurance stowage rock it is necessary to create volumetrically-homogenous, high-density structure with optimal dispersions of hydro silicates [11].

The hydration products of silicate minerals are in the form of tiny crystalline and submicrocrystalline (gellous) particles, and can be seen only by an electron microscope. An electron microscope of fine resolution TESCAN MIRA 3 LMU was used to study the microstructure of filling mixture samples. The results of the study are in figure 3.

Mixture microstructures are inhomogeneous, there is an entwinement of long-size lamina crystals with fine-crystalline new growths on the surface of the filler grains, and there is a non-uniform pore volume void space and numerous cavities, due to water evaporation. Forecasting the strength of such a sample we can say that such a mixture will have low strength characteristics.

![Figure 3. Microphotographs of chip cleavage at various magnifications](image)
For the generalized analysis we chose the following parameters: density, crushing strength, CaO content, Al₂O₃ content, sand SiO₂ content, SiO₂/CaO ratio (conventionally sand/concrete). Samples analysis, picked from the destroyed arrays, demonstrates a wide range of variations in density parameters (the difference in parameters is more than 42 %), the difference in parameters in crushing strength is from 1.35MPa to 14.59MPa, the ratio of Portland concrete to sand in the filling mass is from 3.34 to 11.2 (table 1).

Table 1. The results of a generalized analysis of samples from destroyed arrays

| № sample | Density, g/cm³ | Crushing strength, MPa | CaO content | SiO₂ | SiO₂/CaO |
|----------|----------------|------------------------|-------------|------|---------|
| 1        | 1.44           | 1.35                   | 15.2        | 66.4 | 4.37    |
| 2        | 1.58           | 2.29                   | 7.23        | 81.0 | 11.2    |
| 4        | 1.48           | 1.86                   | 7.11        | 78.0 | 11.0    |
| 5        | 1.45           | 2.1                    | 7.6         | 78.0 | 10.3    |
| 13/2     | 1.69           | 14.59                  | 18.7        | 62.6 | 3.34    |
| 14/2     | 1.69           | 9.2                    | 13.2        | 72.0 | 5.4     |
| 16/2     | 1.68           | 10.48                  | 16.4        | 65.2 | 3.97    |
| 17/2     | 1.53           | 9.05                   | 13.8        | 69.7 | 5.05    |
| 18/2     | 1.707          | 10.71                  | 18.6        | 61.9 | 3.32    |

By SiO₂/CaO ratio the samples can be divided into 2 groups:
1. Additional layer, SiO₂/CaO ratio from 10.3 to 11.2, strength from 1.86 to 2.29 MPa, density 1.45–1.58 g/cm³.
2. Base layer, SiO₂/CaO ratio from 3.32 to 5.45, strength from 1.35 to 14.59 MPa, density 1.2–1.707 g/cm³.

Thus, basing on the results of the study we can say that the variation in CaO content evidences the mixture inhomogeneity when preparing basic materials or mortar mixes.

Density variations from 1.2 to 1.707 g/cm³ can be caused by the inhomogeneous composition of the mixture at the stage of preparing basic materials, non-steady water-cement ration in the filling mixture.

Basing on the results of the works [5, 9–13] and research results of strength variations in massifs we can say about inhomogeneity of the filling mixture, and possible defective mixing of input components in the composite or wrong selection of the input products to form the filling.

To receive a complete picture of the reasons for variations in strength the study of basic materials for the filling mixture has been conducted. The results showed that the main input component of the filling massifs was sand with different characteristics. There is no constant composition of the filling mixture. The composition changes depending on the sand used. There is no coarse of mine stockpile at the enterprise. That was the reason for such a variation of strength of filling massifs, which is impermissible.

To solve this problem we have developed effective compositions with composite bindings and fillers to prepare filling mixtures with the substitution of Portland cement by the composite bindings. It will save up to 40 % of Portland cement and stabilize and improve strength characteristics of the filling mass up to 30 % of the guaranteed quality.

To solve such problems, a complex approach should be applied. So, to receive a quality and durable filling massif a number of other important issues should be solved. The first is possibility to use ashes, slag wastes, DMS, WMS, flotation in filling mixtures both as fillers and as components of the composite binding [1, 5, 6, 7, 13, 14].

To optimize the spending of the Portland cement and prepare quality filling mixtures a wet milling procedure is of special interest, when the binding is activated in the filling mixture [12, 15–18].

Dispersed reinforcement is also promising with technogenic raw material, introducing asbestos cement products wastes as fibro-optics, improving reinforcement of filling massifs and framing schemes of laying roofs for filling massifs.
Special attention should be paid to sand gradation for filling mixture in order to reduce water requirement of mixtures when preserving rheological properties. Introduction of large-size filler into the filling mixtures should also be considered. The technology of stowing operations is also important, exactly continuous feeding of the mixture along the pipeline.

Developing new justified systems of stowing complexes and technological lines of filling mixtures production is a step forward in developing further ore deposits with high economic effect.

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