Technology for Fixing Mine Workings by Spraying Concrete in the Conditions of the Ural Mines

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Abstract. The results of laboratory tests of concrete intended for fixing mine workings in the conditions of the Chebachy mine are presented. The main recommendations for improving the technology of spray concrete work are shown.

1. Introduction
When driving capital, preparatory and rifled underground mine workings, one of the main types of lining is spray concrete. The technology of spraying concrete involves the use of specialized equipment that works on the "dry" or "wet" method.

The use of machines for wet spraying allows to significantly increase the speed of penetration of workings due to their significant productivity and mechanization of the process. A significant advantage of the "wet" technology is the reduction in the rebound of the sprayed concrete material from the workings contour during its application and the initial strength gain due to the use of plasticizer additives and cementitious hardening accelerators.

An analysis of the experience in attaching workings made it possible to establish that the largest share of the cost is materials (> 60%), therefore it seems appropriate to consider the possibility of reducing the cost of materials through the use of rocks from sinking, represented by durable varieties, to work out the technology of coating formation in the process of pilot tests, evaluate the economic efficiency of the transition to a new type of aggregate, determine the need to use various additives that improve technological characteristics of the mortar and the created spray-concrete coating.

2. Relevance, scientific significance of the issue with a brief overview of references
According to the recommendations set forth in [1] sprayed concrete lining, as well as their combinations in the form of anchor-sprayed concrete, arch-sprayed concrete and anchor-sprayed concrete-arch supports, it is allowed to use in horizontal and inclined workings of all kinds, passable in dry and slightly watered massifs (moist soils) not lower than average stability (the estimated allowable technological time of unsecured outcrop of rocks up to 10 days), composed of rocks with uniaxial compression resistance "in the array" (according to BC 2.05.05) of at least 30 MPa.

The use of spray concrete for fastening workings in weakly stable massifs (the estimated allowable technological time of unsecured rock exposure for at least 1 day) alone or in combination with arches is allowed only if there is engineering justification - confirmation by experimental work in construction or other facilities in similar conditions, taking into account applicable technology, available equipment and qualifications drifters.
In all cases of application of spray concrete support, adhesion of spray concrete to the ground should be ensured not less than the tensile strength of the soil itself in a piece for weak and highly fractured rocks and not less than 0.5 MPa for strong rock.

Designs of lining made of spray concrete can be performed depending on the application conditions in the form of a non-reinforced or reinforced metal mesh or fiber coating.

The thickness of sprayed concrete used as a protective coating against weathering of rock outcrop, taken without calculation, should be at least 3 cm.

The thickness of the spray concrete as a protective layer for the working reinforcement should be at least 2 cm.

The thickness of the spray concrete used as a design load-bearing structure alone or in combination with anchors or arches should be assigned at least 5 cm.

Blasting in the immediate vicinity of the sprayed concrete coating is allowed when it reaches a strength of at least 1 MPa (10 kgf/cm²).

According to [2], in addition to the requirements for ordinary concrete (strength characteristics, water resistance, resistance to aggressive influences, etc.), spraying concrete is also presented with additional ones — setting speed of concrete mix within 15–20 min, quick set of strength at an early age, good adhesion to fixed surface, insignificant technological losses of material (“rebound”), low dust formation, higher grade of concrete.

The strength of sprayed concrete should be at least 6 MPa at the age of 1 day and 25 MPa at the age of 28 days.

Satisfactory quality spray concrete can be obtained with a water-cement ratio (W / C) of 0.4 - 0.5, which approximately corresponds to the ductility of a conventional concrete mixture.

Binders must have a brand name of at least 300 (400 is recommended), and in the presence of aggressive water, meet the requirements for salt tolerance.

The use of special quick-setting and quick-hardening cements is effective.

These cements have a setting time of 5 to 15 minutes (beginning - end), are quick hardening (compressive strength at 2 hours is 2 - 3 MPa; 3 days - 20 - 25) MPa; high-quality (grades 300, 400); have high salt tolerance. Shelf life of cements is up to 2 months. in a separate container[3].

3. Problem statement
To determine the suitability of the aggregate for spray concrete, the grain composition provided by the Chebachye underground mine of screening of rocks from sinking, as well as the available screening of rocks of the Sangalyk and Gumbey quarries, was determined.

All presented screenings satisfy the requirements of State standard 8736-2014 Sand for construction work. Technical conditions.

According to [4], the maximum size of coarse aggregate particles should be assigned taking into account the technical characteristics used by concrete spraying machines and the thickness of sprayed concrete coating, but not more than 25 mm, and in coatings up to 5 cm thick, the maximum grain size of coarse aggregate should not exceed 10 mm, and in coatings 5 to 10 cm thick — not more than 15 mm.

The graphs of the distribution of the total residues on the sieve from the particle sizes for screenings Chebachy, Sangalyk, Gumbey show that they are in the recommended area for screenings with a size of 10 mm.

4. Theory
The methodology for selecting [5-12] the composition of the dry mix for sprayed concrete includes:

1. Characterization of materials - cement; sand; crushed stone;
2. Determination of the production coefficient K, depending on production conditions;
3. For subsequent calculations, the average production level, variation coefficient of 13%, production coefficient K = 0.95;
4. Clarification of productivity of spraying concrete machine, m³/h; material hose length, m; hose
diameter, mm The following machines are used at the Chebachye mine: for dry spraying of concrete type SB, BM, Aliva, with an average material hose length of 20 m and a hose diameter of 50 mm; Spraymec machines with a hose length of 10 m and a hose diameter of 50 mm are used for wet spraying;

5. Determination of requirements for spray concrete; compressive strength grade, frost resistance grade, waterproof grade. For the Chebachye mine, spray concrete should have the following characteristics: compressive strength class B25, frost resistance grade F100, and water resistance W4.

6. Preliminary determination of water-cement ratio. Clarification of the water-cement ratio, based on the service conditions of the brand concrete for frost resistance and water resistance;

7. Determination of water flow depending on the size of the aggregate and the rigidity of the spray concrete mixture;

8. Clarification of water flow depending on the type of materials used;

9. Determination of cement consumption per 1 m$^3$ of sprayed concrete;

10. Determination of cement consumption per 1 m$^3$ of dry mix;

11. Determination of the relationship between sand and gravel (the proportion of sand in the aggregate mixture r), depending on the cement grade, modulus of sand size and the required strength of the sprayed concrete (taking into account the coefficient of production conditions);

12. Determination of sand consumption per 1 m$^3$ of dry mix;

13. Determination of crushed stone consumption in 1 m$^3$ of dry mix;

14. Determining the optimal spraying concrete application mode (pressure in the spraying concrete machine and the distance from the nozzle to the concrete surface);

15. The purpose of the hearth flow rate when pumped, depending on the water-cement ratio W / C, cement consumption, productivity of the spraying concrete machine;

16. Determination of the amount of materials to obtain 1 m$^3$ of sprayed concrete by the output coefficient for the estimated calculation of the cost of sprayed concrete;

17. The composition of the applied spray concrete differs from the composition of the initial mixture, since the mixture is compacted and partially lost during the spray process due to rebound of the material;

18. Determination of the setting time of cement mortar with an additive to find the optimal amount of additive is performed on a Vika device;

19. The strength of samples with additives at the age of 1, 3, 7, and 28 days should not be lower than the strength of control samples of the same composition.

5. Practical significance, offers and introduction results, results of experimental research

The results of the selection of the composition of spray concrete mixtures are given in table 1. The compositions are located in the table as the cement-water (C/W) ratio increases.

Table 1. Compositions and physicomechanical properties of shotcrete mixtures on the aggregate of the Chebachy mine.

| № | Consumption of materials per 1 m$^3$, kg | Cone draft, cm | Density, kg/m$^3$ | The limit of compressive strength, MPa | C/W |
|---|----------------------------------------|----------------|-----------------|---------------------------------------|-----|
| Ch9 | 505 | 1340 | 393 | 7,5 | 2240 | 1,7 | 8,3 | 12,7 | 1,28 |
| Ch 10 | 497 | 1388 | 355 | 7 | 2242 | 2,0 | 9,0 | 14,1 | 1,4 |
| Ch 1 | 612 | 1228 | 361 | 8 | 2200 | 3,8 | 15,2 | 22,1 | 1,7 |
| Ch 2 | 683 | 1175 | 360 | 8,5 | 2218 | 2,51 | 14,0 | 18,0 | 1,9 |
| Ch 1 | 804 | 1037 | 376 | 6 | 2218 | 3,91 | 18,7 | 23,6 | 2,13 |
| Ch 4 | 859 | 859 | 400 | 8 | 2194 | 5,12 | 20,7 | 25,4 | 2,14 |
| Ch 12 | 852 | 952 | 392 | 7 | 2196 | 7,08 | 21,6 | 28,4 | 2,17 |
| Ch 5 | 983 | 780 | 406 | 7,5 | 2170 | 5,57 | 24,5 | 29,1 | 2,42 |
| Ch 25 | 929 | 864 | 362 | 7,5 | 2156 | 6,1 | 27,4 | 34,7 | 2,57 |
| Ch 30 | 1005 | 783 | 374 | 8 | 2162 | 6,8 | 29,6 | 41,8 | 2,67 |
The composition of Ch1 is an indicative composition that is currently being used at the Chebachye mine. To clarify the strength characteristics of this composition in underground conditions, it is recommended to determine the strength of spray concrete using non-destructive testing methods and, when obtaining an indicator of compressive strength with a high value, it is possible to correct the obtained compositions Ch2 and Ch3 or to allow the use of compositions Ch4, Ch12, Ch5.

A smooth increase in indicators violates the uneven change in water flow, which ranges from 355-406 kg / m³. Fluctuations in water flow are associated with a change in the water demand of the aggregate, a decrease in mobility and an increase in viscosity is observed visually with stirring. This does not allow to achieve a constant value of the immersion of the cone. The reason for this behavior of the mixture is the presence in the aggregate of inclusions capable of swelling, in an amount of 1 to 13%, related to metasomatites (chemically modified rock). The ability to swell was evaluated by the method of determining the clay component in clay raw materials.

Despite fluctuations in water flow in the investigated compositions, the law of constancy of water demand is observed, which shows that for fine-grained concrete, water consumption is maintained at a constant level while maintaining the mobility of the mixture by increasing the volume of cement paste. These findings coincide with the output parameters of the studies presented in [13-21].

The consolidated graph of strength indicators shows that in order to obtain grade B25 shotcrete (32.7 MPa), it is necessary to maintain the cement-water ratio at a level of at least 2.5. With this value of the cement-water ratio and the required mobility of the mixture, a significant cement consumption of over 900 kg / m³ is required.

On aggregates "Gumbeysky" and "Sangalyk" concrete class B25 is achieved with lower C / W = 1.95 and 2.2 and, accordingly, cement consumption of 700 and 790 kg / m³, with an equal flow rate of water - 361 and 359 l / m³.

6. Conclusions
The determination of the softening coefficient for various compositions with different fillers showed:

1. The softening coefficient of the compositions of shotcrete on the aggregate represented by the Chebachye mine depends on the strength characteristics of concrete. The smallest softening coefficient 0.52 was determined for composition Ch1, where the tensile strength at the age of 28 days was 18 MPa. For more durable compositions (23-29 MPa), the softening coefficient is in the range of 0.7-0.91. This does not guarantee the full water resistance of the compositions on the aggregate represented by the Chebachye mine.

2. The softening coefficient of shotcrete compositions on standard aggregates (Gumbeysky, Sangalysky) exceeds 0.8 regardless of strength indicators (composition CB15, where the tensile strength at the age of 28 days was 15.3 MPa) and are completely waterproof.

3. The reason for the low water resistance of the compositions on the aggregate represented by the Chebachye mine should be considered the presence of metasomatites in the rock, which are prone to swelling and cause a decrease in concrete strength.

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