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## APPLICATION OF THE ALKALI-FREE SETTING ACCELERATOR AND SUPERPLASTICIZER FOR SHOTCRETE SUPPORT OF MINE WORKINGS

**Abstract.** The advisability has been studied to apply alkali-free setting accelerator and superplasticizer for shotcrete support of mine workings at the Zhomart mine. The wet process sprayed concrete technology for the mine workings has been fully developed. The maximum layer thickness of the surface has been from 10 cm to 12 cm. The steam curing has been used, and as a result, the fast-setting of the applied concrete has been observed. The test results have demonstrated that the increasing in the lifespan of concrete and doubling all strength characteristics should consequently lead to the security upgrade of production processes with stability and maintenance of the shotcrete support.

**Key words:** mine tests, setting accelerator, spraying of shotcrete, wet process, mine workings, superplasticizer, investigation, a rebound, setting, hardening, strength, cone slump, concrete mix.

### Тау-кен жұмыстарын шартты бетонды бекіту үшін сілтісіз қабылдау үдеткіш мен гиперпластикаторды қолдану

**Андатпа.** Жомарт кенішінің жағдайында кен қазбаларын бетонды бетонмен бекіту үшін сілтісіз қатаю үдеткішін және гиперпластикаторын пайдалану мүмкіндігі зерттелді. Шахталы бетон қоспасын кен орындарына қолдану бөлігінде ылғалды бетон әдісінің технологиясы толығымен әзірленді. Алынған қабаттың бетіндегі максималды қалыңдығы (10 см-ден 12 см-ге дейін) қолданылатын бетоннан бу шығару және жылдам орнату арқылы жылыды шығарумен бірге жүрді. Сынақ нәтижелері бетонның «өмірінің» артуы, сондай-ақ барлық беріктік сипаттамаларының екі есе ұлғаюы, сайып келгенде, тұрақтылықты қамтамасыз ету және тірек жағдайын сақтау кезінде өндірістік процестердің қауіпсіздік деңгейінің жоғарылауына әкелетінін көрсетті.

**Түйін сөздер:** шахталық сынау, үдеткіш, бүріккіш бетонды қолдану, ылғалды әдіс, бекіту, кен қазбалары, гиперпластикатор, зерттеу, кері бұру, баптау, қатаю, беріктік, конустың шөгугі, бетон қоспасы.

### Применение бесщелочного ускорителя схватывания и гиперпластикатора для торкрет-бетонного крепления горных выработок

**Аннотация.** Изучена целесообразность применения бесщелочного ускорителя схватывания и гиперпластикатора для торкрет-бетонного крепления горных выработок в условиях рудника Жомарт. Технология мокрого метода торкретирования в части нанесения торкрет-смеси на горные выработки была отработана в полном объеме. Максимальная толщина полученного слоя на поверхности (от 10 см до 12 см) сопровождалась выделением тепла путем выделения пара из нанесенного бетона и быстрым схватыванием. Результаты испытаний показали, что увеличение времени «жизни» бетона, а также рост в два раза всех прочностных характеристик в итоге приведет к повышению уровня безопасности производственных процессов с обеспечением устойчивости и сохранением состояния крепи.

**Ключевые слова:** рудничные испытания, ускоритель схватывания, нанесение торкретбетона, мокрый способ, крепление, горные выработки, гиперпластикатор, исследование, отскок, схватывание, твердение, прочность, осадка конуса, бетонная смесь.

#### Introduction

The current state of the shotcrete support at the mines of Kazakhmys Corporation, LLP, can be described as a step-by-step process. It consists in the fact that a mix of concrete, aggregates and water is sprayed to rock, support or other surface with using the compressed air. Thus, this mix adheres firmly to the surface, and it hardens.

The mines of Kazakhmys Corporation, LLC, use shotcrete as follows:

- to create the lining materials for rock, and to protect it from weathering and flaking;
- to develop the waterproofing, corrosion-resistant, antiseptic, fire-resistant and airtight coatings;
- to strengthen and repair concrete supports;
- to reduce the surface roughness of the unlined ventilation ducts.

The works at the mines have resulted that the used shotcrete advantages are the high quality and reliability of the coatings created.

Disadvantages of the material and its spraying procedure include as follows:

- the need to use aggregates only with small fractions, thus, it causes a large cement overspend compared with the standard concrete;
- the low productivity of the used machines, complexity of their design and high wear and tear of parts;
- dust formation during the working operation;
- the need to dry the washed out aggregates to the required moisture content.

The deficient efficiency of the shotcrete support widely used at the mines of Kazakhmys Corporation, LLP, often leads to security issues,

namely, to rock falling in the working area, as result, it is accompanied with the high risks such as:

- injuries to miners in the tunneling and drifting faces,
- the spalling of rock pieces from the roof and sides of the mine working during the gadding, support and loading<sup>1</sup>.

Therefore, in order to reduce the high risks, the MasterRoc SA 167 alkali-free setting accelerator and MasterGlenium UG 3553 superplasticizer for shotcrete support have been tested in the mine. The pilot tests have been performed by the existing wet process sprayed concrete technology. The testing purpose was to determine the probability and practicability to apply the MasterRoc SA 167 alkali-free setting accelerator and MasterGlenium UG 3553 superplasticizer and to accelerate the

<sup>1</sup>The practical guide for mining engineer. – Karaganda: Kazakhmys Corporation LLP, 2019. – 365 p. (in Russian)

shotcrete support process of workings at mines of Production Association «Zhezkazgantsvetmet», Branch of Kazakhmys Corporation, LLP.

The tests have been performed at the «Pass to ore pass-4» and «Haulage roadway 4» of the Zhomart mine. In order to test, previously imported components have been applied as follows: sand brought from Kyzylzhar open pit mine, Firm Samga supplier; cement from plant «Shymkentcement» in big bags under GOST 31108-2016 CEM II/A-Sh 32.5N; MasterGlenium UG 3553 – 120 kg; MasterRoc SA 167 – 600 kg. The MasterGlenium UG 3553 and MasterRoc SA 167 chemical additives made by Master Builders Solutions Central Asia, LLP, as a result, they have been provided free of charge<sup>2-4</sup>.

The main 3 test objectives have been formed:

- to measure the rebound value;
- to determine the average thickness of the sprayed shotcrete layer in 1 pass;
- to define the maximum thickness of the layer.

#### Research methods

The tests have been performed by comparing the parameters of the concrete spraying of mine workings with using MasterRoc SA 167 setting accelerator, MasterGlenium UG 3553 superplasticizer and without using additives. The literature review, study of the scientific and technical documentation on shotcrete support of mine workings, the pilot tests at the Zhomart mine, the analysis and synthesis of research results with their the critical evaluation are able to substantiate further development and improvement of the research object<sup>5</sup> [1, 2]. The basic technical characteristics of the used materials have been studied and described. MasterRoc SA 167 is a high-performance, alkali-free setting accelerator applied in the spraying of concrete. It is a liquid additive

**Table 1**  
**Technical data of MasterRoc SA 167**  
**Таблица 1**  
**Технические характеристики MasterRoc SA 167**  
**Кесте 1**  
**MasterRoc SA 167 техникалық сипаттамалары**

Form	Suspension
Color	From beige to white
Density (20°C)	1.47 ± 0.03 g/ml
Acidic balance pH	2.7 ± 0.5
(1:1 aqueous solution) Viscosity 1	750 ± 250 mPa.s
Thermal resistance	from +5°C to +35°C
[Na <sub>2</sub> O] Equivalent (% of bonding agent weight)	<0.1%
Chlorides	no

**Table 2**  
**Technical data of MasterGlenium UG 3553**  
**Таблица 2**  
**Технические характеристики MasterGlenium UG 3553**  
**Кесте 2**  
**MasterGlenium UG 3553 техникалық сипаттамалары**

Form	Viscous liquid
Color	Yellow
Density (20°C)	1.02-1,06 kg/m <sup>3</sup>
Acidic balance pH	(20°C) 4-6
Chlorides	<0.1%

adjusted with dosing to achieve the desired setting and curing time.

MasterGlenium UG 3553 is a superplasticizer designed specifically for the underground construction. A latest-generation shotcrete additive has been based on the modified polycarboxylate esters. Based on the comparison with traditionally used superplasticizers, MasterGlenium UG has a more powerful dispersion effect, and it is able to provide an increase in the lifespan of shotcrete mixes, and to contact effectively with all types of cements.

The test process has been performed as follows. During the

first workings, the composition used in the shotcrete of mining has been adjusted with reducing the quantity of water. Thus, the strength concrete characteristics have been increased by changes in moisture content of aggregates, and by using MasterGlenium UG 3553 superplasticizer. Its application was able to achieve the necessary mix mobility for the quality spraying by pumps installed on the shotcrete plant. And it could reduce the quantity of water in the mix, and as a result, it had a positive effect on concrete strength parameters. The optimal composition base on the

<sup>2</sup> General construction cements. Specifications. / GOST 31108-2016 (in Russian)

<sup>3</sup> Cements and materials for cement production. Methods of chemical analysis. / GOST 5382-91 (in Russian)

<sup>4</sup> Cements. General technical conditions. / GOST 30515-2013 (in Russian)

<sup>5</sup> Alejano R., Perucho Á., Olalla C., Jiménez R. Rock engineering and rock mechanics: structures in and on rock masses. – London: CRC Press, 2014. – 1st Edition. – 372 p. (in English)

Table 3

Actually obtained compositions in the laboratory

Таблица 3

Фактически полученные в лаборатории составы

Кесте 3

Зертханасында нақты алынған рецептуралар

Mix code	Basic composition	With additive	
Mix information	lab test	lab test	
Concrete class	m350	m350	
Analysis date	07.07.2022	07.07.2022	
Cement source			
Cement dosage (kg/m <sup>3</sup> )	500	500	
W/C ratio	0,54	0,41	
Water (LTR/m <sup>3</sup> )	273,5	208	
N.Sand Source (PKZ 0-8 mm)	13yr3`678757852`y4`17654bgb		
N.Sand (Kg/m <sup>3</sup> )	–	–	
N.Sand (Kg/m <sup>3</sup> )	not applicable	not applicable	
Admixture source	not applicable	MGlenium UG 3553	
Admixture (%)	0	1,5%	
Fresh Concrete Test	MasterRoc SA 167 flow rate	–	–
	5 min. Slump / Flow Table (cm)	27	26
	60 min. Slump / Flow (cm)	18	25
	120 min.Slump / Flow (cm)	14	24
	1 day	3.24 Mpa (10%)	9.03 Mpa (28%)
	3 days	11.1 Mpa (34%)	28.4 Mpa (88%)
	7 days	18.7 Mpa (58%)	41.7 Mpa (130%)
	28 days	28.8 Mpa (90%)	61.8 Mpa (192%)

materials presented by specialists of Zhomart mine has been developed before with using the laboratory conditions. The basic and developed compositions are demonstrated in Table 3 with indication of Abrams cone slump, lifespan of mix mobility and strength determination with the destructive method<sup>6</sup>. The lifespan of concrete and doubling all strength characteristics have increased by MasterGlenium UG 3553 superplasticizer. Consequently it would lead to the security upgrade of production processes with the stability and maintenance of the shotcrete support.

The panel 55 has demonstrated the pilot tests of wet process sprayed concrete technology. Shotcrete mix has been applied by filling through a

cement screen and aggregates directly into the mixer. Two mixes per 4 m<sup>3</sup> each have been prepared<sup>7</sup>. The first mix has been made with the existing composition. Thickness of application was 1-3 cm, and rebound – 20-30%. Shotcrete of 140 m<sup>2</sup> have been performed. Concrete rate per 1m<sup>2</sup> at a thickness of 1cm has been as follows: 2300 kg / 100 cm × 1.25 × 1.1 ~ 32 kg.

The concrete density of 1 m<sup>3</sup> was 2300 kg. The average rebound was 25%. Surface roughness coefficient was min 1.1. The second mix has been prepared with using MasterRoc SA 167 alkali-free setting accelerator and MasterGlenium UG 3553 superplasticizer. The thickness of application was 10-12 cm, and the rebound was 5-6%. Shotcrete of 32 m<sup>2</sup> have been performed.

Concrete rate per 1 m<sup>2</sup> at a thickness of 1cm has been as follows: 2300 kg / 100 cm × 1.055 × 1.1 ~ 27 kg.

During the shotcreting of an average thickness of 5 cm with using MasterRoc SA 167 and MasterGlenium UG 3553, savings per 1 m<sup>2</sup> has been equal of 25 kg of the finished concrete. The labor costs for the repeated spraying and appreciation of equipment have been used.

#### Results and discussions

Thus, the results on the pilot tests have been obtained as follows:

1. The wet process sprayed concrete technology for the mine workings has been detailed developed in detail.

2. The Y-shaped dispenser has been blocked on the setting accelerator supply. Thus, the initial strength could not be measured by reason

<sup>6</sup>Kazakhmys Corporation LLP. Instruction on the supports of mine workings at the Zhomart mine, 2020 (in Russian)

<sup>7</sup>Cements. Methods for determination of standard consistency, times of setting and soundness. / GOST 310.3-76 (in Russian)

of frequent stops of the Spraymec concrete spraying machine.

3. The maximum thickness of the resulting layer on surface was 10-12 cm. The steam curing and the fast-setting have been applied. The thickness has been determined by the screwdriver testing for leakage detection, using MasterRoc SA 167 alkali-free setting accelerator and MasterGlenium UG 3553 superplasticizer.

4. In the shotcrete mix preparation process at the Zhomart mine, the previously developed compositions have been adjusted, and thus, a concrete mix has been obtained meeting to the relevant parameters for the high-quality spraying.

5. Pieces of the solid mass have blocked the cells of the concrete loading hopper at the spraying concrete from the mixer. Thus, these pieces have been removed manually.

Some deviations have been revealed during the pilot tests:

1. The Y-shaped dispenser has been regular blocked on the Spraymec machine to supply setting accelerator.

2. Pieces of the solid mass with a size of 40-250 mm have been fallen into the Spraymec loading hopper.

As a result, the following work recommendations have been formed:

To improve the quality of work on wet concrete spraying, it has been recommended to install directly the concrete mixing plant in the mine in order to establish an accurate dosing process of all used components (cement, ballast and water). Currently, many varieties of the mobile concrete mixing plant have been applied.

To perform the large-scale tests of the wet process, using these recommendations. To determine the mine workings with a length of at least 100 m.

These tests should be included as follows:

- to measure the normative shotcrete strength.

- to determine the adhesion properties of the sprayed composition from surface of the mine working under the mine environment conditions.

- to define the mixture stability to the physical and mechanical effects related to production of mining workings and motion of the mobile equipment.

- to perform a comparative timing test, where the workings should be with identical intervals of the base mix without additives and the developed composition using the MasterRoc SA 167 setting accelerator and MasterGlenium UG 3553 superplasticizer

3. To reduce cement consumption with the accurate dosage of the components, thus, it should lead to saving in the composition.

4. To additionally install a calibration grid with a vibrator screen to load into the mixer using the uneven sand fraction and large stones. The close-mesh screen should improve the sand purity and the final mix quality. It should reduce the risks related to failure of the planned indicators due to the plugs in nozzle and concrete spraying unit.

5. To train the personnel to perform works on the Normet

Spraymec concrete spraying machine (the start of work, dispenser setting and preparation for spraying, washing and blowing the surface, concrete spraying, the end of work, washing out, etc.)

6. To increase the sand quality, the providing input control of materials would be recommended for the content of dust and clay particles, and clay in the stones by the sampling each batch.

7. To keep a record of the flow rate of water supplied to the mix for proper dosing without a concrete mixing plant.

8. In order to avoid the non-compliance with the formulation in the absence of the concrete mixing plant, we suggest the possibility to use the finished dry mix of MasterRoc STS 1600 for the wet process, and the control of the water supply in liters to mix<sup>8</sup>.

#### Conclusion

As a result, it is possible and expedient to apply MasterRoc SA 167 alkali-free setting accelerator and MasterGlenium UG 3553 superplasticizer for shotcrete support of workings at mines of Production Association «Zhezkazgantsvetmet», Branch of Kazakhmys Corporation, LLP. At this stage, it is efficient to proceed to large-scale pilot testing at the mines of Production Association «Zhezkazgantsvetmet», Branch of Kazakhmys Corporation, LLP, to adjust and develop the wet process sprayed concrete technology with the chemical additives, and the relevant parameters of the finished concrete in the shotcrete support.

<sup>8</sup>Test acts of MasterRoc SA 167 alkali-free setting accelerator and MasterGlenium UG 3553 superplasticizer produced by Master Builders Solution Central Asia LLP (BASF Central Asia) (in Russian)

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