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RECOMMENDATIONS FOR SUPPORTS OF MINE WORKINGS IN UNDERGROUND MINING

Abstract. The exploration of mine workings and analysis of the underground mining documentation have been resulted that the maximal volume of inrush was observed during the roadway driving along the strike with impact angle of Δ = 0°, and the minimal volume of inrush was found during the crosscutting with impact angle of Δ = ±90°. By reason of the insufficient efficiency of the applied shotcrete supports, the rock inrush in the working area could lead to the high risks of injury to the miners in the breakage and drifting faces, the detachment of rock slabs from the side walls or roof of the workings during the gadding, support and loading. In order to reduce the high risks, the pilot tests of MasterRoc STS 1510 shotcrete mix have been performed. The results have demonstrated that this mix is suitable and recommended to use in the mining as an independent support and as part of the anchor structure and metal mesh.

Key words: *underground development, occurrence, tectonic disturbance, inrush, strength, support, tests, mining and geological conditions, shotcrete, mix, anchoring, setting.*

Жер асты кенін өндіру мысалында бұрғыруларды бекіту бойынша ұсыныстар

Аңдатпа. Тау-кен қазбаларының жай-күйін зерттеу және жер асты кенішінің құжаттамасын талдау нәтижелері бойынша Δ = 0° кездесу бұрышы бар тау жыныстарының соғуы бойымен дрейфтерді жүргізу кезінде құлаудың ең үлкен көлемі байқалатыны анықталды; құлаудың ең аз көлемі – кездесу бұрышы Δ = ±90° болатын орттарды бату кезінде. Қолданылатын құйма-бетонды бекітудің жеткіліксіз тиімділігіне байланысты түптік кеңістіктегі тау-кен массасының құлауы жоғары тәуекелдерге әкеледі: кеншілерді тоқтау және батып бара жатқан беткейлердің жарақаттануы, төбедегі тау массасының бөліктерінің қабыршақтануы, саңылауларды бұрғылау, бекіту және тиеу кезінде шахтаның бүйірлері. Жоғары тәуекелдерді азайту мақсатында MasterRoc STS 1510 бүріккіш бетон қоспасының тәжірибелік сынақтары жүргізілді. Нәтижелер қоспаның шахта жағдайында тәуелсіз төсем ретінде де, якорь төсемінің және металл тордың бөлігі ретінде де қолдануға жарамды және ұсынылғанын көрсетті.

Түйінді сөздер: *жер асты қазбалары, кен орны, тектоникалық бұзылулар, құлау, беріктік, бекіту, сынау, тау-кен-геологиялық жағдайлар, бүріккіш бетон, қоспа, адгезия, қату.*

Рекомендации по креплению горных выработок на примере подземного рудника

Аннотация. По результатам обследования состояния горных выработок и анализа документации подземного рудника установлено, что наибольший объем вывалов наблюдается при проходке штреков по простиранию пород с углом встречи Δ = 0°; наименьший объем вывалов – при проходке ортов с углом встречи Δ = ±90°. Вывалы горной массы в призабойном пространстве вследствие недостаточной эффективности применяемого торкрет-бетонного крепления приводят к возникновению высоких рисков: травмированию горнорабочих очистного и проходческого забоев, отслаиванию кусков горной массы с кровли и бортов выработки при бурении шпуров, креплении и заряжании. С целью снижения высоких рисков проведены опытно-промышленные испытания торкрет смеси MasterRoc STS 1510. Результаты показали, что смесь пригодна и рекомендована для применения в условиях рудника как в качестве самостоятельной крепи, так и в составе анкерной крепи и металлической сетки.

Ключевые слова: *подземная разработка, месторождение, тектонические нарушения, вывал, прочность, крепление, испытания, горно-геологические условия, торкрет-бетон, смесь, сцепление, схватывание.*

Introduction

The Abyz occurrence is located in the Central Kazakhstan fault zone. Therefore, its rocks had the significant processes of the dynamic metamorphism (foliation, grinding, mylonitization) and the intense hydrothermal-metasomatic changes. These changes have been referred to the tectonic regional formations with the propylitic, propylite-beresite and beresite statistically stable associations. The sequence of hydrothermal and metasomatic formations has been directed from propylites (chlorites) to bresites (sericites). The hydrothermally processed metasomatites are unstable, and they can lose strength during flooding[1]. The peculiarity of this occurrence is an ore zone with some lens of ore bodies and zones of the disseminated mineralization, and frequent alternation of rocks in the ore zone differing in strength, soaking and strength.

The underground developments of this occurrence are made with a sublevel caving system at a sub-level of 540 m under the sides and bottom of the waste mine which has been flooded with water for some time. Results of exploration of mine workings and analysis of documentation have been found as follows:

1. The tectonic disturbance, fractures and rock contacts have a steep rock-fall and strike relevant to the strike of ore bodies.

2. The enclosing rocks outside the ore zone are strong, very strong and less fractured. Thus, their competence category can be estimated in the range from the above-average to stable constant.

3. The ore zone has the individual ore bodies (lens) and a frequent alternativeness of various types of hydrothermally altered rocks which differing in strength and competence.

4. The mine workings passed in the cross strike of ore bodies (roadways) are estimated as stable in the strong rocks, and as medium stable in the weak rocks.

5. The roof and sides of the mine workings passed in the cross strike of ore bodies (roadways) with the contour blasting operation are caved by systems of steeply dipping fissures. In some places, inrushes are observed between anchors and with bare anchors. Their length is about 0.7-1.0 m.

6. The development working and break-off conducted within the near-ore zone can lose the competence during the direction of the mine workings along strike of rocks[2].

7. The maximal volume of inrush is observed during the roadway driving along the strike with impact angle of Δ = 0°, and the minimal volume of inrush is found during the crosscutting with impact angle of Δ = ±90° (Figure 1).

8. The applied anchor Monomatic cannot install a support with the admissible installation angle of the support (Figure 2). Measurement of the overall length of

[1]*Instructions for the selection and use of lining at the Abyz field. – Karaganda: Kazakhmys Corporation LLP, 2021 (in Russian)*

[2]*The practical guide for mining engineer. – Karaganda: Kazakhmys Corporation LLP, 2019. – 365 p. (in Russian)*

Table 1

The technical characteristics of MasterRoc STS 1510

Кесте 1

Техникалық сипаттамалар MasterRoc STS 1510

Таблица 1

Технические характеристики MasterRoc STS 1510

Form	Powder (dry mix)
Color	Gray
Density	1700 kg/m^3 in dry condition
Maximum particle size	After spraying of 2200-2400 kg/m^3
Maximum particle size	Up to 3 mm
Tensile strength after 1 hour	At least 2 MPa
Tensile strength after 6 hours	At least 3.5 MPa
Tensile strength after 24 hours	At least 15 MPa
Tensile strength after 28 days	More than 35 MPa

the beam of the Monomatic №71 drilling machine is 5.40 m. The drilling of a roof support of the actual length of the beam is 4.30 m. The design height of the mine workings is 4.20 m, and width is 3.8 m. To construct the design height of the mine workings and the length of the drilling machine boom[3], the maximum anchoring angle is 700.

9. The mine workings have the areas with the difficult mining and geological conditions.

10. The low efficiency of the shotcrete support used at the Abyz mine leads to the safety problems. Therefore, rock inrush in the working area can have the high risks of injury to miners in the breakage and drifting faces, the detachment of rock slabs from roof or the side walls of the workings during the gadding, support and loading.

Thus, in order to reduce the high risks, the mine tests of MasterRoc STS 1510 shotcrete mix have been performed. The pilot tests have been done in compliance with the current wet shotcrete process.

The test objective was to detect the probability and practicability to apply MasterRoc STS 1510 shotcrete mix in order to accelerate the shotcrete support process of the mine workings at the Abyz mine of Kazakhmys Corporation LLP.

In order to introduce the advanced technological solutions in the mining operations at the Kazakhmys Corporation LLP, the pilot tests of the shotcrete mix using the AC-1 rotating machine (Tornado Torcrete LLC) have been conducted at the Abyz underground mine. These tests have been performed in the airway of the transport slope (horizon of +490).

The basic three objectives have been applied as part of the exploration:

1) the rebound value should be measured;

2) the average thickness of the sprayed shotcrete layer during one drift should be defined;

3) the maximum layer thickness should be determined [1].

Research methods

Literary sources have been reviewed. The scientific and technical documentation on shotcrete supports of the mine workings have been studied. Pilot tests have been made at the Abyz mine. Research results with their critical estimation to substantiate the further development and improvement of the studied object have been analyzed and generalized. The basic applied technical characteristics of the materials have been studied and described[4] [2, 3].

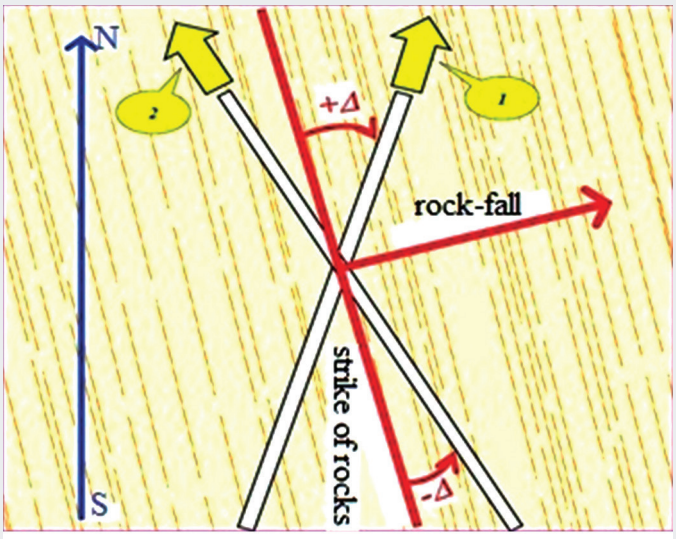
The mine tests of the MasterRoc STS 1510 shotcrete mix in compliance with the current dry shotcrete process using the AC-1 rotating machine (Tornado Torcrete LLC) have been performed.

The basic technical characteristics of the used materials have been studied and described.

MasterRoc STS 1510 is a ready-to-use, cement-based dry mix modified with a dry setting accelerator and microsilica powder. This mix has been developed for the dry concrete spraying of the mine workings. During the concrete spraying this dry mix can give the previous strength forces, the less rebound of particles and the thickest possible layers of the spraying (Table 1).

Results and discussion

All stages of these tests have been performed on the AC-1 shotcrete machine (Figure 3). The shotcrete mix has been sprayed with using the current dry shotcrete process. All rules of shotcrete spraying, i.e. washing



1 – with a positive impact angle;
2 – with a negative impact angle.

Figure 1. Scheme to determine an impact angle Δ between the strike of steep rock-fall and direction of roadway driving.

Сурет 1. Тіке батқан тау жыныстары қабаттарының соғуы мен жылжу бағыты арасындағы түйісу бұрышы Δ тұрғысынан анықтау схемасы.

Рис. 1. Схема для определения в плане угла встречи Δ между простиранием толщи крутопадающих пород и направлением проходки штрека.

[3]*Recommendations for fixing mine workings at the Abyz mine. – Karaganda: Kazakhmys Corporation LLP, 2019. (in Russian)*

[4]*Alejano R., Perucho Áu., Olalla C., Jiménez R. Rock engineering and rock mechanics: structures in and on rock masses. − CRC Press, 2014. − 372 p. (in English)*

of the surface before spraying, keeping of the nozzle angle of 90 degrees relative to the mine workings, distance of the nozzle of 1-1.5 m to surface of the side or roof of the mine workings have been kept.

During these tests, 12 m^2 of mine workings have been shotcreted along the sides. Thickness of spraying was 50-120 mm. In the area of beacons, the thickness of spraying was 300 mm depending on the mine working relief.

The roof has not been shotcreted by reason of the air supply interruptions (compressor shutdown at Abyz mine). During the concrete spraying the rebound was no more than 10%. 42 Packages of 25 kg have been loaded.

Thus, the results of tests have been found as follows:

- MasterRoc STS 1510 shotcrete mix had the good glutiness, adhesion to rocks, high setting rate and strength in the first hours of curing. Its composition has been laid without the falling or slumping of the applied layers;
- adhesion and setting time of the mix could create the shotcrete with a thickness of 50 to 300 mm in the places of beacons on sides and roof of the mine workings for one cycle;
- during the exploration of mine workings the rebound loss of material after spraying has amounted no more than 10% (Table 2).

The main factors affect quality, cost and labor capacity as follows:

- there is no need to prepare the mix, i.e. it takes up a considerable amount of the working time;
- there is no need for double and triple passage of the same mine workings, i.e. to achieve the design thickness during one drift;
- the loading rates of the receiving bunker of the shotcrete machine and the continuous, non-stop operation.

Also important factor is that the manufacturer of this mix gives a guarantee for the technical requirements of the finished mix and its further operation in compliance with permissible standards.

The practice has noted that the spraying of shotcrete mix without additives and modifiers in the composition of concrete is able to apply a layer of not more than 10-30 mm in one drift with a rebound of 50-70%. Thickness of a sprayed layer, capacity and the amount of rebound are the main indicators to calculate the economic evaluation for using of a particular method of shotcreting in the mine. Thus, it significantly affects the cost of shotcrete operations[5, 6].

Conclusion

Based on the obtained results, MasterRoc STS 1510 mix is suitable and recommended to apply at the Abyz mine of Kazakhmys Corporation LLC as an independent support and as part of the anchor structure and metal mesh.

It is recommended to examine the probability to purchase one carload (64 tons) of MasterRoc STS 1510 mix and the AC-2 shotcrete rotating machine in order to continue the spraying of this mix with the technical support of Optimus kz LLP for the partial introduction of the dry shotcrete process in the production cycles of the mine. Thus, it should significantly increase labor capacity and improve the quality characteristics of the applied concrete. As a result, the cost of the work in progress should be reduced.

Material of MasterRoc STS 1510 can have the early setting (2-3 min) and strength of shotcrete (after 60 min – more 2.0 MPa). Thus, the design thickness of shotcrete mix of 50-120 mm or more for one spraying can be used.

The shotcrete layer with a thickness of 3-5 cm has the role to protect the mined rocks from breaking due to weathering process and access of water and oxygen, and its secondary role is a support in view of thickness of a layer of shotcrete. Therefore, the rock pressure can exceed

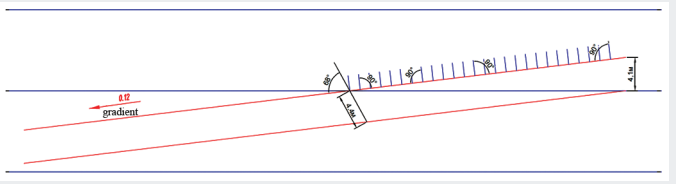


Figure 2. Installation angle of Monomatic drilling machine.
Сурет 2. Мономатты бұрғылау жабдығын орнату бұрышы.
Рис. 2. Угол установки бурового оборудования Мономатик.

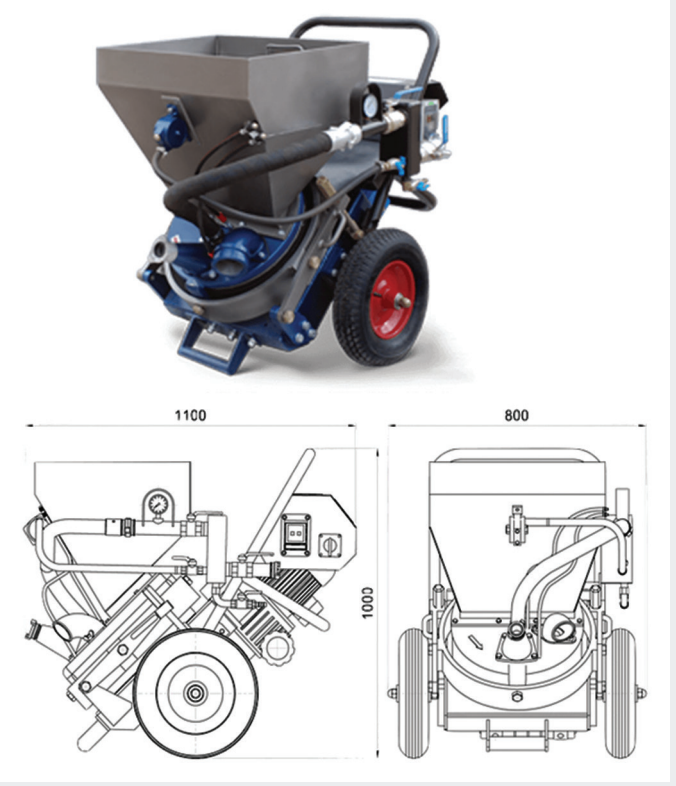


Figure 3. AC-1 shotcrete machine.
Сурет 3. АС-1 штепсельдік бетонды орнату.
Рис. 3. Торкрет установка АС-1.

[5] *Amanzholov E.A. Mounting of mine workings. / Presentation on the course of training of mountain masters. – 2016 (in Russian)*
[6] *ACT of test testing of the finished dry shotcrete mix MasterRoc STS 1510 manufactured by Master Builders Solutiond Central Asia LLP (BASF Central Asia) and shotcrete plant AS-1 manufactured by Tornado Shotcrete LLC. – 2021 (in Russian)*

Table 2

Test results

Кесте 2

Тест нәтижелері алынды

Таблица 2

Полученные результаты испытаний

Material	Setting time of mix, min	Thickness per one spraying	Rebound losses, %	Strength, MPa
Concrete sprayed with the wet shotcrete process without MasterRoc STS 1510 additives	>180 min	5-10 mm	More 50%	After 24 hours – up to 5 MPa
MasterRoc STS 1510	Up to 10 min	50-120 mm and more	No more than 10%	After 24 hours – up to 15 MPa

the tensile strength of sprayed concrete for bending and compression, i.e. it directly depends on thickness of the layer and armoring. As a result, it is recommended to apply the anchor-mesh-sprayed concrete system of the reinforced-combined supports.

MasterRoc STS 1510 is recommended to apply in the difficult mining and geological conditions. Also it can be used in conditions of water drip and thus, the drainage boreholes, troughs and other methods of water flow control should be applied.

As a result, in order to prevent detachment of rocks from the sides, the roof and sides of the mine workings should be anchored during the driving of the field roadways along the strike of the ore zone in all types of rocks.

In order drive the mine workings in the difficult mining and geological conditions, the changes should, if necessary, be made in passports of supports by the geological and geotechnical service and should be approved by a chief engineer of the mine.

In the future, the geological and technical departments of the mine should examine the geology of the site in plan to design the mine workings. The changes should be added to the local projects in terms of direction of the mine workings during the crossing of faults and contacts.

It is recommended to add the Sandvik DS211L-M rock bolter machine to the investment plan for the quality anchoring of the mine workings. Now, the drilling equipment at the mine does not properly install the anchors[7].

Before purchasing of the Sandvik DS211L-M rock bolter machine, the design parameters of the mine workings should be reviewed to ensure the quality anchoring with the Monomatic drilling machine.

In order to prevent shifts on contour of solid mass and sudden inrushes, the mine supports should not lag behind in conformity with requirements of the «Instructions to select and use of supports at the Abyz mine». The high-quality ventilation of the mine workings should be constantly established.

[7]*Yun A.B. Development and substantiation of the parameters of the mining and technical system for the integrated development of the Zhezkazgan deposit in the conditions of replenishment of the retiring capacities of mines. / Dissertation for the degree of PhD. – M.: NUST «MISiS». – 2016 (in Russian)*

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