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PREPARING SOLUTIONS BASED ON INDUSTRIAL WASTE FOR FRACTURED SURFACE STRENGTHENING

Abstract. Results of longstanding researches of Satbayev University scientists on the development of modified building materials to strengthen cracked mountain structures based on industrial waste are considered. Industrial processing of technogenic raw materials (enrichment and processing waste, overburden and enclosing rocks), which is similar in composition to natural and used in conventional trend, scarcely different from industrial processing of mineral raw materials. Creation of effective technologies for the processing of technogenic raw materials is an urgent task, which make it possible to obtain competitive products from it for various industries.

Various methods of preparing solutions for strengthening of fractured rocks and building structures are analyzed. Research results of tailings of the Balkhash Mining and Metallurgical Combine and preparing solutions for strengthening fractured rocks and underground mining structures are presented. Rock mass strengthening in cracked areas is achieved by adding substances into the cracks, which after hardening and solidification with rocks, increase its shearing resistance characteristics. The most widespread hardening methods were cementation during mine workings (underground structures) in fractured rocks.

Significance of obtained results for construction industry is in expansion and reproduction of raw material base of building materials industry through the use of Mining and metallurgical complex waste (tailings) and development of resource-saving technologies. Practical significance of work is in the detailed development of modified method for the production of building materials and products.

Key words: field development, mine site, fracturing, cracks, rock mass caving, strengthening, mining waste, building materials, modified solutions.

Introduction. Mining enterprises of Kazakhstan pay special attention to the industrial safety of subsurface development. One of the real examples is geomechanical researches conducted by Satbayev University in the framework of the project "Risk reduction of technogenic disasters by developing innovative management methods" (2015-2017). Currently, within the framework of Project "Innovative methods development for prediction and assessment of rock mass state for the prevention of technogenic nature emergencies" researches on study and ensuring mountain structures stability are conducted by young scientists.

The content of the work. Problems of mine workings stability in fractured rocks are the most hard-solving problems in the construction and operation of mining enterprise. These problems intensely exist in the polymetallic deposits of Kazakhstan: Tekeli, Akzhal, Verkhnekairaktinsky, Karagaylinsky, Tekeli. Ores and enclosing rocks of these deposits are complicated by fractured deformations and make its development more difficult.

Research results of mine workings at the Akzhal mine (at mine site and underground horizons) showed that the largest number of dumps is confined to fractured rocks, and dumps volume is increasing as far as workings' standing. Observations of the mine workings, which were performed on the fractured rocks, revealed that they are stable for a month. After two or three months, pins are formed up to 10-15 cm

in size. Pins and outfalls arise and develop within six months, roof collapses become acquainted in the form of domes. This acutely increases volume and complexity of the tunneling works, as well as the cost of workings fixing and repairing.

Stability of adjacent rock masses is determined by the degree of their fracturing. Strengthening technology of fractured massif should ensure the complete cracks filling in the massif with different composition and securely bind individual structural blocks into a single whole. One of the effective methods to prevent this type of rock deformation is their artificial strengthening which allows to provide the necessary slopes stability of inoperative mine sites and in some cases to prevent possible rock collapse in weakened areas, in others - significantly reduce the volume of overburden operations [1-3].

The most common strengthening method is rock cementation. Such method of ensuring the slopes stability of mine sites is complex task, solution of which should include not only parameters determination of stable slopes, but also their management to achieve the best economic results in the development of natural resources. Use of artificial strengthening of rocks and massifs allows increasing gradient of slope in areas with unstable rocks. Strengthening advisability is established by technical and economic calculations. Strengthening of some areas is achieved with the help of substances that significantly increase its strength characteristics. Adding substance in the massif is made under pressure, using cement solutions, silicates and polymer resins as hardening material, confirmed by publications of leading scientists in the field of mining [4-10].

To prevent the collapse of underground workings (underground structures), passed through fractured rocks, roof timber with metal fencing mesh and shotcreting are used. However, roof rocks cleavage of transport drift and significant rocks destruction indicates that this timber does not solve the problem of stability ensuring of workings and does not prevent deformations development. As a result, after 2-3 years of standing workings, timber are damaged and major repairs are required. Therefore, effective solution of controlling issue on geomechanical properties of rocks is particularly important for adjacent rock mass of mine sites and for underground workings passed through fractured rocks [11-13].

Researches on rock fracturing and methods development of controlling their properties were carried out for the conditions of Akzhal deposit. Analysis of geological conditions of the field and workings condition passed by fractured rocks showed that fracture systems of heavy pitch have great influence on the workings' stability. By nature, cracks vary from smooth, wavy to uneven, splintering. The width of the crack opening does not exceed 3 mm and averages 1.5-1.8 mm. Based on conducted researches on samples of fractured rocks, it was found that rocks have different degrees of fracture. According to the degree of change, they were classified into 3 groups: particularly, highly and partially disturbed (table 1).

Various strength characteristics of fractured rocks predetermine the need for differentiated approach to managing the rocks properties with fracturing intensity.

Table 1 – Classification of rocks, their physical and mechanical properties, structure and texture

№ group	Fracture intensity	Rock characteristics	№ sample	Compres-sion strength on MPa	Rock strength by Proto-diakonov*f*	Srtucture	Texture	Fracture plane state	Fracture positioning
I	Particularly fractured	Quartz-sericite chlorite	9	43,4	3	Small acinose	Fissile	Fracture planes are cragged	Fractures of parallel lamination
			10	44,8	3				
			11	65,5	5				
	Mean value		12	51.2	4				
II	Highly fractured	Sericite-quartz.	2	84	6	Small acinose	Massive	Fracture planes are cragged, hackly	Fractures multioriented
			4	103,6	7				
			14	106,4	8				
	Mean value			62,7	7				
III	Partially fractured	Diorite Quartzite	3	140,0	10	Small acinose	Massive	Fracture planes are cragged, hackly	Fractures multioriented, parallel lamination
			5	154,0	11				
			7	162,4	12				
	Mean value			152,1	11				

For highly fractured rocks with strength factor of 5-8, it is recommended that workings walls be coated with modified concrete in combination with roof timber. Application of waterproofer coat will significantly reduce rock pressure on timber, limit the weathering spread and delamination of overlying layers and prevent properties change of fractured rocks. To study the physical mechanical properties (PMP) of solutions of various compositions, cubic samples of cement and water with modifying additives were prepared in various percentages of cement weight. Research results are shown in figure 1.

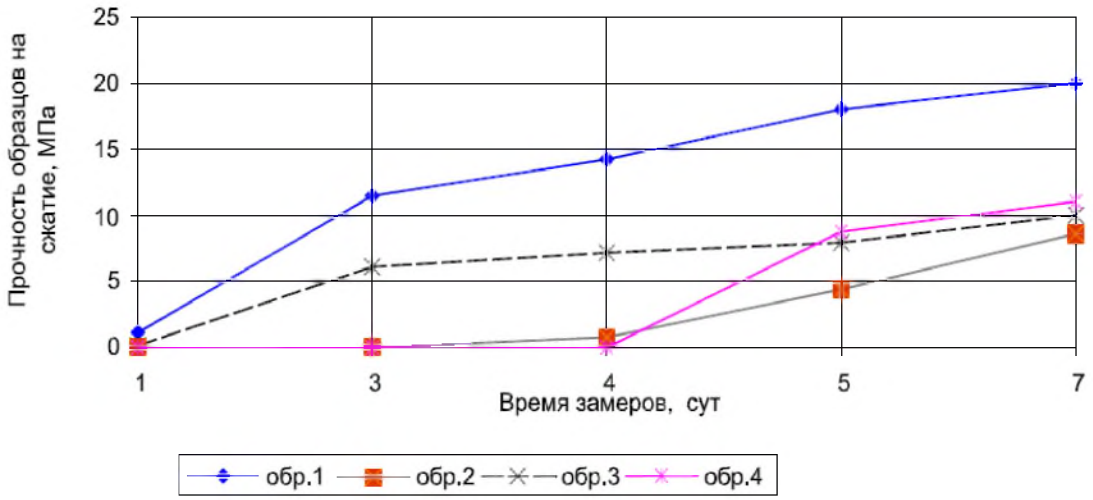

Figure 1 – Change dependency of concrete strength with various additives on time:
1 - Movilita additive; 2 - additive of sodium silicate and calcium chloride;
3 - additive of construction emulsion PVA-M; 4 - addition of high molecular polymer polyacrylamide

For safe deposit development on the underlying horizons, in order to prevent cavings, and also to suppress the dust formation of dumps, insulating solution was developed by our scientists in cooperation with "CelSIM" laboratory, composition of which is given below.

Known solution for strengthening fractured rocks described in the book Pevzner M.E. [14]. It contains cement, water and additive - calcium chloride in the amount of 1-2.2% by weight of cement. Solution has high cost.

Known composition for hardening rocks [15] and contains following components: wt,%

Carbamide resin brand KSM	88-92,
Watersoluble polyester blend	4-6
Aluminum chromophosphate	4-6,

Solution has high cost and must be prepared directly at the well.

We are declaring solution that includes cement, filler and water. The basis of the invention is solution creation for strengthening fractured surfaces, having low cost, sufficient fluidity to fill small cracks and adhesion to rocks, high strength of material obtained and allowing recovering mining waste - concentration plants tailings.

Invention relates to mining and building materials, namely to strengthen rocks with binder solution. Technical result: utilization of mining wastes - concentration plants tailings, achievement of high fluidity of solution, adhesion to rocks and strength of composition obtained.

To achieve this result, composition for strengthening fractured rocks containing cement , filler and water, according the invention results as the filler contains concentration plants tailings and additionally contains Movilite dispersion polymer powder with the following equivalence ratio, wt. %:

Cement	30-35
Concentration plants tailings.	45-50
Movilite dispersion polymer powder	0,8-2
Water other	

Specified equivalence ratio is optimal and obtained experimentally. On the one hand, necessary fluidity of solution and adhesion, and on the other hand, to obtain the material of the necessary strength after setting it with rocks. In each particular case, to select optimal composition of bonding solution, it is necessary to study the physical and chemical composition of tailings of various concentration plants.

For example, Portland cement M 400 of Karaganda cement plant and tailings of the Balkhash mining and metallurgical plant are acceptable for the Akzhal mine and Portland cement of the Shymkent cement plant and tailings of the Akbakay concentration plant itself are acceptable. The X-ray appearance of the Balkhash mining and metallurgical complex tailings (figure 2) shows mainly three components with 4.23 diffraction lines; 3.238; 2,455; 2.28; 2.237; 2.127; 1.977; 1.817; 1,669; 1.658; 1.541; 1.454; 1,388; 1,373, corresponding to quartz.

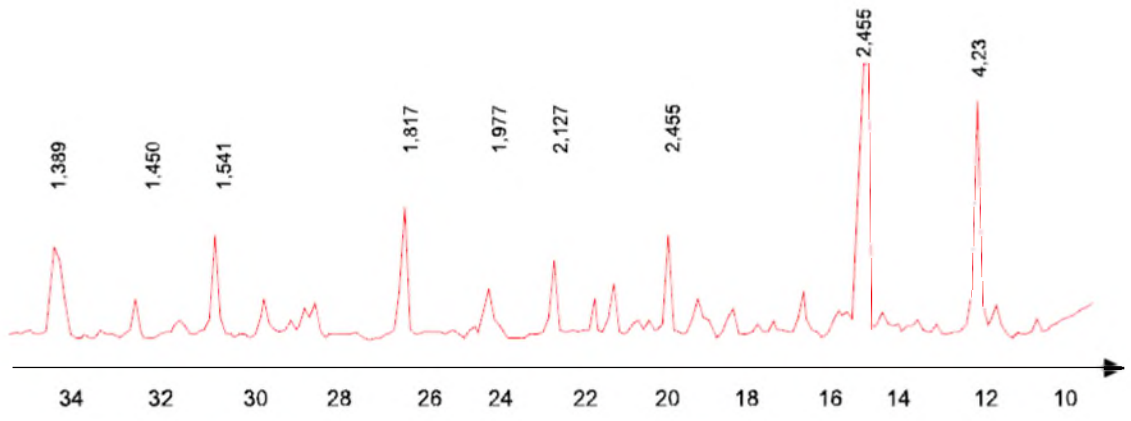

Figure 2 – The X-ray analysis of Balkhash mining and metallurgical complex tailings

After components dosing the cement, tailings and movilit are loaded into concrete mixer and mixed thoroughly. Then add water and mix. Finished composition is delivered by underground workings and pumped into disturbed pillars and roof of the chambers. To determine the strength, 4x4x16 cm samples were molded from the composition and compacted on vibrating plate for 45 sec. After a day, the samples were removed from the molds and stored in humid conditions for 28 days, and then physical and mechanical tests were carried out, results of which are presented in tables 1 and 2.

Table 1 – Physical and mechanical properties of the solution

	Composition of the solution, wt.%			Index			
	Cement	Concentration plants tailings	Movilit	Water	Compressive strength, MPa	Bending strength MPa	Slump, мм
Sample 1	30	50	4	16	32,5	4,7	150
Sample 2	32,5	47,5	3,5	16,5	35,6	5,2	145
Sample 3	35	45	3,0	17,0	37,2	5,8	143

Table 2 – Physical and mechanical properties of the composition

Index	Sample 1	Sample 2	Sample 3
Compressive strength, MPa	22,5	25,6	27,2
Frost resistance, cycles	10	12	15

Technical novelty of the created solution is confirmed by the patent of the Republic of Kazakhstan for the invention [19].

Analysis of mining and construction works showed that acid-resistant cements are the most widely applicable at present, which are obtained by mixing filler with sodium silicate and accelerator of setting and hardening process - calcium chloride of 30% concentration with a density of 1280 kg / m^3. Therefore, liquid sodium silicate with modular number of 2, 5 and density of 1330 kg / m^3 and 1250 kg / m^3 was used to create modified solution. In the course of researches on solutions with high - molecular polymer additives the following polymers were tested: polyvinyl acetate dispersion - PVAD, builder dispersion "Movilit VDM-618". Observations results showed that the best adhesion with humid rocks is achieved in solutions of modified building dispersion "Movilit VDM-618 compositions (see figure 3, lines 1, 5). Therefore, solution modification of construction dispersion "Movilit VDM-618" significantly improves its properties; the set of strength occurs in humid aggressive environment. In addition, "Movilit" building dispersion adding to solution gives the properties of gas and water resistance, resistance to aggressive underground environments. To study adhesion, solution modified with various additives was applied to fractured rocks. Test results are shown in figure 3.

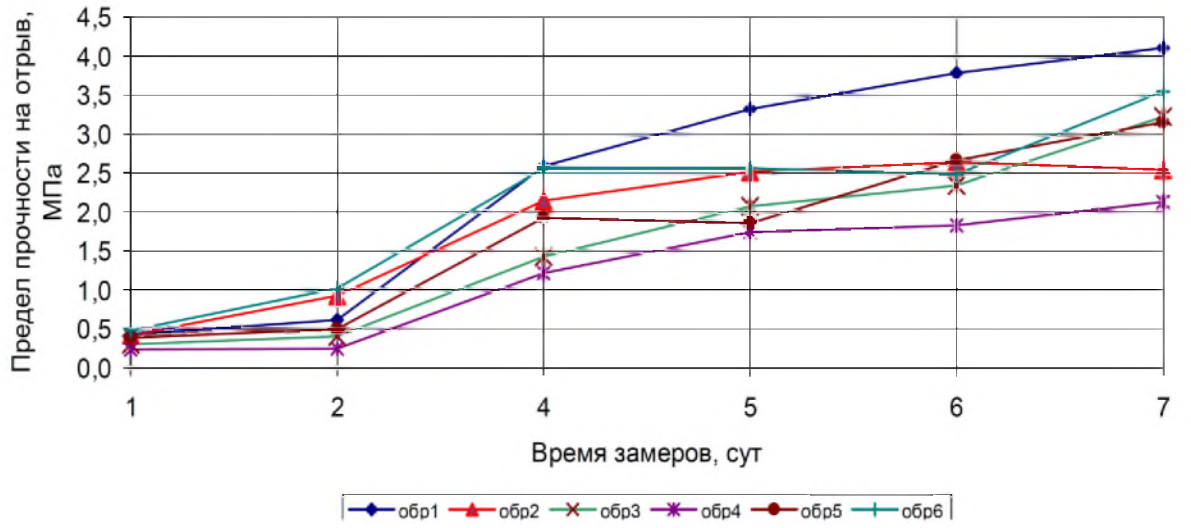

Figure 3 – Influence of time on the adhesion change of modified cementations' compositions with fractured rocks:
1 – with the addition "Movilit VDM-618"- 5% of cement composition;
2 - with the addition of sodium silicate with δ = 1.33 g / cm^3 and m = 2.5 calcium chloride;
3 - with the addition of sodium silicate with δ = 1.25 g / cm^3 and calcium chloride;
4 - with the addition of PVAD; 5– with the addition of PAA

Pilot tests of obtained composition in underground workings of the Akzhal mine showed its sufficient penetrability and rapid polymerization with its own high mechanical properties [20].

Conclusions. Use of concentration plants tailings will contribute to reduce composition cost and increase material strength. With more than 35% increase of cement amount and more than 4% increase super plasticizing additive - composition cost increases. With less than 30% decrease of cement amount and super plasticizing additive less than 3% decrease - strength of the obtained material increases.

Increasing of concentration plants tailings by more than 50% will lead to decrease in the solution fluidity and its adhesion to rocks, and less than 45% decrease will increase the composition cost.

Thus, use of developed solutions allows obtaining the roof with high strength and higher adhesion. It should also be noted that new solution use ensures strengthening of weak sections of open pit sides and underground mining structures and can significantly reduce the damage effect of concentration plants waste on environment.

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ӨНДІРІС ҚАЛДЫҚТАРЫ НЕГІЗІНДЕ ЖАРЫҚШАҚТАЛҒАН БЕТТЕРДІ БЕКІТУ ҮШІН ЕРІТІНДІЛЕР ЖАСАУ

Аннотация. Сәтбаев университеті ғалымдарының өнеркәсіп қалдығы негізінде жарықшақталған тау жыныстарын нығайту үшін жаңартылған құрылыс материалдарын жасау жөніндегі көпжылдық зерттеулерінің нәтижелері қарастырылды.

Табиғи құрамы жағынан жақын техногенді шикізаттарды (байыту қалдығын, аршыма және жанама тау жыныстары) және дәстүрлі бағыттарда пайдаланылатын минералды шикізаттарды өнеркәсіптік қайта өңдеудің айырмашылығы жоқ. Сондықтан, техногендік шикізатты қайта өңдеудің одан өнеркәсіптің түрлі салалары үшін бәсекеге қабілетті өнім алуға мүмкіндік беретін тиімді технологияларын құру бүгінгі күннің маңызды мәселесі болып отыр.

Карьер беткейлерінің құлауы мен шөгуінің алдын алу үшін үлкен массивтердегі тау жыныстарының жасанды түрде беріктігін ұлғайтуға келмесе де, жекелеген беткей деформацияларын және жасанды бекемдеу әдісімен карьер беткейінде опырылудың алдын алу қазіргі таңда отандық және шетелдік карьерлерде қолданылуда. Көптеген карьерлерде жұмыс істемейтін ернеуді түзетін тау жыныстарының құрылымы мен физикалық-механикалық қасиеттері біртексіз болып келеді. Карьер алаңындағы тау жыныстары біртекті болып түзілген күннің өзінде кен орнында, әдетте көптеген тектоникалық бұзылыс аймағы жиі кездеседі.

Тектоникалық бұзылыс аймағы, өз кезегінде өлшемдері мен кеңістікте таралуына байланысты беткейлер мен ернеудің орнықтылығына мейлінше кері әсерін тигізеді. Мұндай жағдайда бекіту арқылы тау жыныстарының үгілуі мен опырылуын баяулатуға, карьер беткейінің опырыла құлауының және тау жыныстарының сырғу беті арқылы жылжуының алдын алуға болады.

Мақалада жарықшақталған карьер беткейі мен құрылыс нысандары қабырғаларын бекіту үшін қажет ерітінділерді алу мүмкіндігі зерттелген. Балқаш тау-кен металлургия комбинатының (БТКМ) байыту қалдықтарын зерттеудің және жарықшақталған тау жыныстары мен құрылыс нысандарын нығайту үшін ерітінділерді алу нәтижелері келтірілген.

Әлсіреген учаскелердегі тау жыныстары массиві мен құрылыс қабырғаларының бекітілуіне, жарықшақтарға арнайы ертінді енгізу арқылы жүзеге асырылады, олар қатайғаннан кейін нысанның жылжу кедергі қабілетін арттырады. Бекемдейтін затты массивке енгізу қысым жасау арқылы жүзеге асады, бекемдейтін материал ретінде цемент ерітінділері, силикаттар және полимерлік материалдар қарастырылған. Бекіту әдістерінің арасында ең көп таралғаны – ол кен қазбаларын (жерасты құрылыстарын) жарышақталған тау жыныстарында жүргізу кезінде цементтеу. Қолдану аясы – қатты жарықшақты үгітілмелі және жартылай жарлыдан бастап ірі тасты құм мен жұмыртастарға дейінгі тау-кен жыныстарының массиві.

Құрылыс индустриясы үшін нәтиже маңызы құрылыс материалдар өнеркәсібінің шикізат базасын кенметаллургия кешен қалдығын (байыту фабрикалары қалдығын) пайдалану және ресурстарды үнемдейтін технологияларды дамыту арқылы құрылыс материалдар өнеркәсібінің шикізат базасын молайту және қайта жаңғырту болып саналады. Жұмыстың практикалық маңыздылығы – құрылыс материалдары мен бұйымдарын өндірудің модификацияланған әдісінің жасалғандығында.

Түйін сөздер: кен орындарын игеру, карьер, бұзылу, жарықшақ, тау-кен массивінің опырылуы, бекіту, тау-кен өндіріс қалдықтары, құрылыс материалдары, ерітінділер.

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СОЗДАНИЕ РАСТВОРОВ НА ОСНОВЕ ОТХОДОВ ПРОИЗВОДСТВА ДЛЯ УКРЕПЛЕНИЯ ТРЕЩИНОВАТЫХ ПОВЕРХНОСТЕЙ

Аннотация. Рассмотрены результаты многлетних исследований ученых Satbayev Unibersitu по вопросам разработки модифицированных строительных материалов для укрепления ослабленных трещинами горных сооружений на основе отходов производства.

Промышленная переработка техногенного сырья (отходы обогащения и переработки, вскрышные и вмещающие породы), близкого по составу к природному и используемого в традиционных направлениях, практически не отличается от промышленной переработки природного минерального сырья. Создание эффективных технологий переработки техногенного сырья, позволяющих получать из него конкурентоспособную продукцию для различных областей промышленности, является актуальной задачей.

Если для предупреждения обрушений и оползней искусственное повышение прочности больших массивов пород практически пока неосуществимо, то предупреждение деформаций отдельных уступов и предотвращение осыпеобразования с поверхности откосов путем искусственного укрепления находит сейчас применение на отечественных и зарубежных карьерах. На большинстве карьеров горные породы, слагающие нерабочие борта, неоднородны по своей структуре и физическим и механическим свойствам. Даже в однородных изверженияx породах карьерного поля насчитывается множество зон тектонической нарушенности.

В зависимости от их размеров и пространственной ориентации они оказывают более или менее значительное влияние на устойчивость уступов и бортов. С помощью укрепления можно замедлять процессы выветривания и осыпания пород, предупреждать обрушения уступов и осыпание пород с поверхности откосов.

В статье проанализированы различные способы создания растворов для укрепления трещиноватых горных пород и строительных сооружений. Приведены результаты исследования хвостов обогащения Балхашского горно-металлургического комбината (БГМК) и получения растворов для укрепления трещиноватых горных пород и подземных горных сооружений.

Упрочнение массива горных пород на ослабленных участках достигается введением в трещины веществ, которые после отвердевания и схватывания с породой увеличивают ее характеристики сопротивления сдвигу. Введение упрочняющего вещества в массив осуществляется под давлением, а в качестве упрочняющегося материала нами рассматриваются цементные растворы, силикаты и полимерные смолы. Наибольшее распространение среди методов упрочнения получила цементация при проведении горных выработок (подземных сооружений) в трещиноватых породах. Область ее применения – массив, сложенный породами от сильнотрещиноватых скальных и полускальных до крупнозернистых песков и галечников при наличии в породах трещин, обеспечивающих доступ цементного раствора в трещину.

Значимость полученных результатов для строительной отрасли заключается в расширении и воспроизводстве сырьевой базы промышленности строительных материалов за счет использования отходов ГМК (хвостов обогащения) и разработки ресурсосберегающих технологий. Практическое значение работы состоит в том, что детально разработан модифицированный способ производства строительных материалов и изделий.

Ключевые слова: разработка месторождений, карьер, нарушенность, трещины, обрушения горного массива, укрепление, отходов горного производства, строительные материалы, модифицированные растворы.

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