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ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

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TECHNOGENIC WASTE FROM COAL MINING - A PROMISING RAW MATERIAL FOR THE PRODUCTION OF BUILDING CERAMICS

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Abstract. This study addresses the urgent need for effective disposal methods for overburden rock produced during coal mining. These man-made formations represent large volumes of waste with negative environmental and landscape impacts. The rational use of overburden is therefore a key task, offering both ecological and economic benefits for mining regions. The paper presents a comprehensive analysis of the physical, mechanical, chemical, and mineralogical properties of overburden rocks. Composition was evaluated based on lithological type, depth of occurrence, and geological formation conditions. Special attention is given to the presence of natural radionuclides, as well as rare earth and noble microelements with potential value. The content of water-soluble salts influencing processing behavior is also identified. The molding and structural-mechanical properties of masses derived from overburden rocks were assessed. Experimental results show that additives such as highly mineralized carbonaceous rocks and aluminum oxychloride significantly enhance the plasticity and strength of the material. The resulting ceramic products demonstrated excellent performance: compressive strength ranging from 33.6 to 48.2 MPa, frost resistance from 50

to 100 cycles, and water absorption between 7.0–10.8%. Overall, the research confirms the technical and environmental feasibility of using overburden rocks in ceramic production. This approach reduces the cost of building materials, lessens dependence on scarce clay resources, and contributes to mitigating environmental damage in coal mining areas.

Key words: overburdened rocks, chemical composition, plastic strength, ceramic products.

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КӨМІР ӨНДІРУДІҢ ТЕХНОГЕНДІК ҚАЛДЫҚТАРЫ – ҚҰРЫЛЫС КЕРАМИКАСЫН ӨНДІРУГЕ АРНАЛҒАН ПЕРСПЕКТИВАЛЫ ШИКІЗАТ

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Аннотация. Бұл зерттеудің өзектілігі көмір өндіру процесінде пайда болған аршылған жыныстарды кәдеге жарату саласында тиімді шешімдерді іздеу қажеттілігімен анықталады. Бұл техногендік түзілімдер қоршаған ортаға және ландшафтқа теріс әсер ететін қалдықтардың айтарлықтай көлемін білдіреді. Сондықтан аршылған жыныстарды ұтымды пайдалану экологиялық жағдайды жақсартуға да, аймақтардың экономикалық дамуына да ықпал ететін маңызды міндетке айналады. Жұмыста аршылған жыныстардың физикалық-механикалық, химиялық және минералогиялық сипаттамалары егжей-тегжейлі қарастырылған. Литологиялық типке, пайда болу тереңдігіне және қалыптасудың геологиялық жағдайларына байланысты құрамға талдау жасалды. Табиғи радионуклидтердің құрамын, сондай-ақ әлеуетті құндылығы бар сирек жер және асыл микроэлементтердің болуын зерттеуге ерекше назар аударылады. Қайта өңдеудің технологиялық

параметрлеріне әсер ететін суда еритін тұздардың ерекшеліктері анықталды. Аршылған жыныстар негізінде алынған массалардың қалыптау және құрылымдық-механикалық қасиеттері бағаланады. Жоғары минералданған көміртекті жыныстар мен алюминий оксихлориді сияқты қоспаларды енгізу шикізат массасының беріктігі мен пластикалық өнімділігін айтарлықтай жақсартуға мүмкіндік беретіні эксперименталды түрде дәлелденді. Алынған керамикалық бұйымдар жоғары көрсеткіштерді көрсетті: қысу беріктігі 33,6-дан 48,2 МПа - ға дейін, аязға төзімділік 50–ден 100 циклге дейін және суды сіңіру 7,0-10,8% аралығында. Зерттеулер құрылыс керамикасын өндіру үшін аршылған жыныстарды пайдалану экономикалық тұрғыдан тиімді және экологиялық тұрғыдан тиімді екенін дәлелдейді. Бұл шешім өнімнің өзіндік құнын төмендетуге, тапшы саз шикізатын ауыстыруға және көмір өндіретін аудандардағы қоршаған ортаға теріс әсерді азайтуға мүмкіндік береді.

Түйін сөздер: аршылған жыныстар, химиялық құрамы, пластикалық беріктігі, керамикалық бұйымдар.

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ТЕХНОГЕННЫЕ ОТХОДЫ УГЛЕДОБЫЧИ – ПЕРСПЕКТИВНОЕ СЫРЬЕ ДЛЯ ПРОИЗВОДСТВА СТРОИТЕЛЬНОЙ КЕРАМИКИ

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Аннотация. Актуальность данного исследования определяется необходимостью поиска эффективных решений в сфере утилизации вскрышных пород, образующихся в процессе угледобычи. Эти техногенные образования представляют собой значительные объёмы отходов, оказывающих негативное воздействие на окружающую среду и ландшафт. Поэтому рациональное использование вскрышных пород становится важной

задачей, способствующей как улучшению экологической обстановки, так и экономическому развитию регионов. В работе подробно рассмотрены физико-механические, химические и минералогические характеристики вскрышных пород. Проведён анализ состава в зависимости от литологического типа, глубины залегания и геологических условий формирования. Особое внимание уделено исследованию содержания природных радионуклидов, а также присутствию редкоземельных и благородных микроэлементов, представляющих потенциальную ценность. Выявлены особенности водорастворимых солей, влияющих на технологические параметры переработки. Оценены формовочные и структурно-механические свойства масс, полученных на основе вскрышных пород. Экспериментально доказано, что введение добавок, таких как высокоминерализованные углистые породы и оксихлорид алюминия, позволяет значительно улучшить прочностные и пластические характеристики сырьевой массы. Полученные керамические изделия продемонстрировали высокие показатели: прочность при сжатии от 33,6 до 48,2 МПа, морозостойкость от 50 до 100 циклов и водопоглощение в пределах 7,0–10,8 %. Исследования доказывают, что использование вскрышных пород для производства строительной керамики является экономически выгодным и экологически целесообразным. Это решение позволяет снизить себестоимость продукции, заменить дефицитное глинистое сырьё и минимизировать негативное влияние на окружающую среду в районах угледобычи.

Ключевые слова: вскрышные породы, химический состав, пластическая прочность, керамические изделия.

Introduction. With the development of technical progress in the world, the amount of various industrial wastes is increasing rapidly. Therefore, it is necessary to constantly look for ways to solve this problem through proper disposal and recycling of waste produced. Growing volumes of waste from the energy and coal industries complicate the environmental situation in areas near coal mines and thermal power plants. One way to recycle solid waste from the fuel and energy complex is to use it as building materials or raw materials for their production.

Ceramic products are durable and relatively inexpensive building materials with high architectural and decorative properties. Stocks of conditioned, high-quality clays used in factories for the production of ceramic products (bricks, tiles, pipes) are quickly depleted (Nori, et al, 2010; Kotlyar, et al, 2017; Gaishun, et al, 2020). For continuous development of the production of ceramic products it is necessary to look for ways of technological transition to new types of raw materials - low plastic loams, low-melting clays with high impurities, as well as aluminosilicate man-made wastes. The experience of domestic (Vereshchagin, et al, 2016; Vasić, et al, 2021; Yavruyan, et al, 2018) and foreign research, in particular from the United States, Western Europe, Japan, and other countries, shows that the production of ceramic products from man-made raw materials is cost-effective

and environmentally appropriate. Since there is no need to extract, transport, and processing of conditioned clay raw materials when it is possible to replace them with production wastes suitable for these purposes (Bosak, et al, 2020; Berdikul, et al, 2022).

Past studies have proved the possibility of using coal industry wastes as burning and baking additives in the production of ceramic products (Abdrakhimova, et al, 2021).

At the world's largest field Ekibastuz (Kazakhstan), during open-pit coal mining a huge amount of waste overburden is formed - overburden rocks are removed to open dumps (Figure 1). During the operation about 4 billion m3 of overburden rocks of coal mining is accumulated. Dumps of overburdened rocks are located near the city limits, occupy large areas, and are up to 100 m high. They significantly worsen the environmental situation in the region and are sources of dust storms, self-combustion, and gas pollution.

Fig. 1. Ekibastuz coal basin (aerial photo, scale 1:1000)

Overburden rocks are formed during the development of the overburden strata of deposits and are represented mainly by sedimentary rocks - clays, argillites, siltstones, loams, sands, gravels, conglomerates, and so on.

Overburden rocks of the Ekibastuz coal basin are represented by argillites and siltstones and are valuable organomineral material. In terms of properties, overburdened rocks are similar to traditional clays and can be used as raw materials for the production of ceramic building materials (Yavruyan, et al,2019).

The aim of the work is a comprehensive study of overburdened rocks from coal mining as the main, environmentally safe raw materials for the production of effective wall and finish ceramic products.

Research objectives: to study the specific activity of natural radionuclides, the content of rare-earth and noble trace elements, the amount and composition of water-soluble salts, chemical and mineralogical composition of overburden rocks of coal mining. Study of structural and mechanical characteristics and molding properties of masses from overburdened rocks. Determination of physical and mechanical characteristics of the obtained ceramic samples using highly mineralized coal rocks as solid additives.

Research Material and methods. When examining the overburdened rocks of coal mining, it was found that argillites and siltstones prevail in the main mass compared to other types of rocks. Argillites and siltstones are mainly represented by clay minerals - kaolinite, hydromica, and partly montmorillonite (Ryzhkov, et al, 2021; Stolboushkin, et al, 2017).

As the object of the study, we used waste coal from the Vostochny coal mine, represented by argillites and siltstones of horizons +50, +100, and +150 m. Overburden horizons of coal mine overburden +50, +100, and +150 m are set from the roof (top) of the coal seam to the ground surface. The properties of siltstones and mudstones of the Ekibastuz coal basin depend on physical and mechanical characteristics, macrostructure, degree of metamorphism, and other factors.

In comparison with traditional clay raw materials, playlists, and siltstones have their specific features, which should be taken into account when evaluating them as raw materials for the production of ceramic products. They have a fairly high average density of 2,55 to 2,70 g/cm3, which largely depends on the fractured nature of the rock. The true density is 2,69-2,74 g/cm^3. The porosity is 1-4 %, and water absorption is on average 2-5 %. When dry, argillites and siltstones (Figure 2) are sufficiently strong (5-20 MPa), but when moistened, the strength decreases sharply. The color of most types of mudstones is gray or dark gray. The structure is aleuro-pelit. The texture is oriented, layered, in some places disorderly. Under a microscope, transmitted light shows mica flakes oriented along layering planes.

a ***b***

Fig. 2. Overburden rocks of the Ekibastuz coal basin:
a - mudstones; b - siltstones

Overburden rocks have certain physical and mechanical properties, which depend on the degree of their metamorphism. In their natural form, they are not soaked in water, which requires their mechanical grinding to break the cementation bonds of the clay components. In general, claystones and siltstones have their characteristics in composition, structural and physical, and mechanical properties compared to other types of clay raw materials. This suggests their potential suitability as a raw material for building ceramics when developing an appropriate methodology for their evaluation, testing, and production technology.

By analyzing the data of the chemical analysis of overburdened rocks of a different lithological type we can judge the quantitative content of rock-forming oxides (table 1).

Table 1 - Chemical composition of overburden rocks

Name of raw materials	Oxides, %											
	SiO_2	Al_2O_3	TiO_2	Fe_2O_3 +FeO	MgO	MnO	CaO	Na_2O	K_2O	P_2O_5	SO_3	п.п.п.
Horizon +50 m												
Argillite	56,7	17,6	0,9	5,6	1,1	0,1	0,2	1,2	1,9	0,25	0,15	12,1
Siltstone	61,1	18,5	1,03	3,4	0,9	0,12	0,85	1,32	2,06	0,25	0,21	10,4
Horizon +100 m												
Argillite	57,7	17,7	0,85	6,4	1,2	0,1	0,77	0,57	2,39	0,3	0,10	11,0
Siltstone	59,9	17,96	0,93	4,18	1,1	0,09	0,74	1,06	2,24	0,25	0,22	10,9
Horizon +150 m												
Argillite	57,7	18,4	0,86	5,6	0,94	0,12	0,73	0,47	2,54	0,38	0,19	11,6
Siltstone	61,3	17,6	0,93	4,02	0,03	0,08	0,56	1,38	2,11	0,28	0,28	10,06

The content of silicon oxide - $Si0_2$ is 56,7-61,3%. It is inbound and free states. Bound silica is a part of clay-forming minerals, free silica is represented by fine quartz impurities, and its content in the samples is 16-25%. According to free quartz content, coal-mining wastes are referred to as the group of raw materials with average quartz content.

The clay-forming minerals and micaceous admixtures include $A1_20_3$, an aluminum oxide. Its content for argillites is 17,6-18,4% and for siltstones 17,6-18,5%. According to the content of aluminum in the calcined state, overburdened rocks belong to the group of semi-acidic raw materials.

The content of iron oxides in the studied samples is 5,6-6,4% for argillites and 3,4-4,18% for siltstones. Iron compounds are represented by pyrite and siderite.

Alkaline-earth metal oxides are part of clay minerals and carbonates. The total content of sodium and potassium oxides in the lithologic types of different bedding horizons ranges from 2,96 to 3,36%. The alkaline oxides Na_2O and K_2O are part of the clay-forming minerals and are also present in the admixture in the form of water-soluble salts. S03-sulfur oxide content does not exceed 0,28%, which is typical for low-sulfur environmentally safe raw material and it allows using the overburdened rocks for the production of ceramic products without any limitation. Overburdened rocks contain organic carbon.

The main physical and mechanical properties of overburdened rocks are density,

natural humidity, compressive strength, and porosity (table 2).

Analysis of the obtained data on density shows that it decreases from +50 m horizon to +150 m horizon, while the density of siltstones is 7-10 % higher than that of claystone and makes 2,3-2,7 g/cm3 for claystone and 2,6 g/cm3.

The natural moisture content of argillites varies from 4,8-5,8 %, siltstones 4,3-4,7 %, and increases from the horizon +50 to the horizon +150 m. The compressive strength of overburdened rocks is 34,7-37,4 MPa for mudstones and 45,0-48,9 MPa for siltstones. When changing the horizon from +50 to +150 m, the compressive strength of siltstones and mudstones decreases. The porosity of mudstones is 12,9-18,7%, siltstones 10,8-19,1%, and increases depending on the horizon from +50 to +150 m.

Table 2 - Physical and mechanical properties of overburden rocks

Name of raw materials	Density, g/cm^3	Natural humidity	Compressive strength, MPa	Porosity, %
Horizon +50 m				
argillite	2,4	5,1	37,4	12,9
siltstone	2,7	4,3	48,9	10,6
Horizon +100 m				
argillite	2,4	4,9	34,9	14,9
siltstone	1.5	4,3	47,0	15,9
Horizon +150 m				
argillite	2,2	5,8	34,7	18,7
siltstone	2,3	4,7	45,0	19,1

Thus, when changing overburden horizons from +50 m to +150 m, indicators of physical and mechanical properties decrease, which is explained by a decrease in the degree of compaction of rocks in this change of horizons, their more significant weathering at the +150 m horizon.

The mineral composition of the studied overburden rocks depending on the lithology and horizon of occurrence is presented in table 3.

Table 3 - Mineral composition of overburden rocks

Name of raw materials	Mineral content, %							
	clay minerals		quartz	feldspar	carbonates	mica	siderite	organic matter
	kaolinite	hydromica						
Horizon +50 m								
Argillite	25-30	20	25	8-12	-	-	-	15
Siltstone	5-10	25	30	20-25	3-5	5	-	10
Horizon +100 m								
Argillite	25	20	30	-	-	-	5	12
Siltstone	5-7	20	40	25	3-5	5	-	8
Horizon +150 m								
Argillite	15	20	40	10	-	-	-	10
Siltstone	3-5	20	50	15-20	5	-	-	5

According to the mineralogy of the clay component, the overburdened rocks belong to the kaolinite-hydrosludite type. Among the nonclay minerals, the studied samples contain admixtures of quartz, feldspar, mixed-layer minerals, as well as organic substances. They can be used as a basic raw material component for the production of ceramic materials (Baidzhanov, et al, 2017).

To study the wastes of coal mining Ekibastuz coal basin used modern spectrometric, optical, thermogravimetric, X-ray phase, and other types of research. There were used modern methods and equipment of accredited, certified laboratories PF JSC "NCECS" (National expertise center), universities of the Republic of Kazakhstan, and operating enterprises for the production of building ceramic materials. The content of water-soluble salts was determined by GOST 21216-2014.

Results and discussion. According to the results of the research, the assessment of the radioactive safety of rocks as raw materials for the production of building materials was carried out. Specific activities of natural radionuclides were determined (Table 4).

Table 4 - Results of determination of specific activities of natural radionuclides

Name of raw materials	Name of natural radionuclides, Specific activity A, Bq/kg			specific activity, A_{eff}, Bq/kg
	radium, ^{226}Ra	thorium, ^{232}Th	potassium, ^{40}K	
Horizon +50 m				
Argillite	37	52	618	158
Siltstone	33	50	604	151
Horizon +100 m				
Argillite	28	39	712	178
Siltstone	24	36	703	165
Horizon +150 m				
Argillite	29	36	685	182
Siltstone	27	34	672	173

Analysis of the obtained data showed that overburdened rocks, by the standards of radiation safety, can be used without restrictions for the production of all types of building materials.

The content of rare-earth and noble elements in the overburdened rocks is relatively low and is of no value for their industrial extraction. The content of hazardous elements (lead, chromium, beryllium, arsenic, antimony, gallium, mercury, etc.) is below the maximum allowable concentrations and in general positions the rocks as relatively environmentally safe raw materials (Table 5). The obtained data were compared with the content to be quantified.

Table 5 - Results of determination of trace elements in the composition of raw materials

element	Content in samples , g/t						Content to be quantified, g/t
	Horizon +50 m		Horizon +100 m		Horizon +150 m		
	argillite	siltstone	argillite	siltstone	argillite	siltstone	
1	2	3	4	5	6	7	8
Barium	400	400	400	400	400	400	1000
Beryllium	20	8	20	8	20	8	50
Boron	<10	<10	<10	<10	<10	<10	200
Vanadium	90	60	70	40	40	50	100
Wassmuth	10	10	10	10	10	10	20
Tungsten	10	10	10	10	10	10	50
Gallium	<3	<3	<3	<3	<3	<3	20
Germanium	<3	<3	<3	<3	<3	<3	3-10
Gold	1	1	1	1	1	1	3-10
Yttrium	<3	<3	<3	<3	<3	<3	3-10
Ytterbium	<3	<3	<3	<3	<3	<3	3-10
Indium	2	1	2	1	2	1	3-10
Cobalt	20	20	20	20	20	10	100
Manganese	700	700	700	600	800	800	1000
Copper	30	30	30	30	30	30	100
Molybdenum	<3	<3	<3	<3	<3	<3	100
Arsenic	100	100	100	100	100	100	300
Nickel	30	30	40	30	30	30	100
Tin	3	3	3	3	3	3	50
Platinum	10	10	10	10	10	10	-
Mercury	0.3	0.3	0.3	0.3	0.3	0.3	1-0.5
Scandium	20	20	20	20	20	20	100
Antimony	30	30	30	30	30	30	300
Strontium	280	210	250	200	210	200	1000
Lead	15	17	16	18	17	18	100
Tantalum	100	100	100	100	100	100	1000
Chromium	40	20	20	30	30	20	100
Zinc	100	100	100	100	100	100	100

Determination of the amount and composition of water-soluble salts by the water-extraction method showed that the content of salts in overburdened rocks is small, characterized by a high degree of homogeneity, and does not require special technological measures for their decontamination (Table 6).

Table 6 - Changes in the composition of the water extract of overburdened rocks

Name of raw materials	HCO_3, %	Cl^-, %	SO_4, %	Ca^{++}, %	Mg^{++}, %	K^+, %	Na^+, %
Horizon +50 m							
Argillite	0,037	0,152	0,029	0,009	0,004	0,003	0,109
Siltstone	0,044	0,085	0,089	0,010	0,004	0,004	0,101
Horizon +100 m							
Argillite	0,039	0,149	0,029	0,007	0,003	0,003	0,115
Siltstone	0,055	0,090	0,093	0,009	0,002	0,002	0,106
Horizon +150 m							
Argillite	0,039	0,155	0,070	0,008	0,003	0,005	0,132
Siltstone	0,049	0,089	0,090	0,010	0,005	0,010	0,089

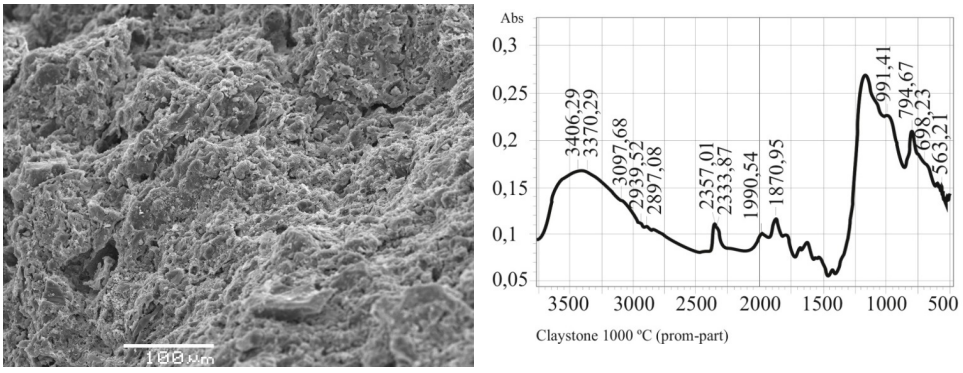
Petrographic studies of the studied rocks showed that they are mainly composed of clay minerals: kaolinite and hydromica; clastic rocks in the form of quartz and feldspars, ferrous minerals, and carbonate inclusions. All samples contain organic matter in the form of elongated irregularly shaped concretions; the number of inclusions of organic matter varies from 5 to 10 % for siltstones and from 10 to 12 % for mudstones. Thin strips of organic matter are observed in the rocks.

The argillite of the +50 m horizon has a pelitic structure. Grain size ranges from 0.01 to 0.001 mm, and grain shape is isometric, less often irregularly elongated, which is characteristic of organic remains. The texture of the claystone is finely banded, which is caused by changes in the concentration of carbonate grains and the orientation of elongated particles of organic matter.

The rock (Figure 3) contains calcite in the form of colorless isometric grains sized 0.003 to 0.008 mm with high birefringence. There is a minor content of colorless volcanic glass with negative relief. Colorless quartz with low positive relief and birefringence is observed, as indicated by gray interference colors. The argillite contains organic matter in the form of black concretions; the number of grains varies from layer to layer from 80 to 90 %. The clayey component is kaolinite, less frequently hydrolysludite-kaolinite, with kaolinite grains up to 0.005 mm in size.

The siltstone of the +50 m horizon has a siltstone structure with grain sizes ranging from 0.1 to 0.005 mm and is dominated by 0.07-0.01 mm grains. The rock contains strongly corroded quartz with direct extinguishing. Feldspar grains are strongly altered, many of them completely transformed into hydromica with preservation of the primary form of feldspar grains. Mica is represented by elongated, well-formed grains with direct extinguishing and bright greenish-blue interference colors. Organic matter in the form of elongated irregularly shaped scabs of brownish-brown coloration is observed. The clayey part of the siltstone is represented by hydromica and kaolinite minerals.

Characteristic areas of the overburden microstructure were studied using a scanning electron microscope. The microtexture of the mudstones is uniform, with individual larger aggregates of irregular shape, predominantly 20-50 μm in size.



a ***b***

Fig. 3. Micrographs of the structure of the claystone of the +100 m horizon, magnification, respectively: 150^0 (a); 750^0 (b), scanning electron microscope

In addition to X-ray diffractometry by international crystallographic and crystal-chemical databases on minerals and their structural analogs, infrared absorption spectra of carbonaceous argillites of overburdened rocks were studied (Figure 5).

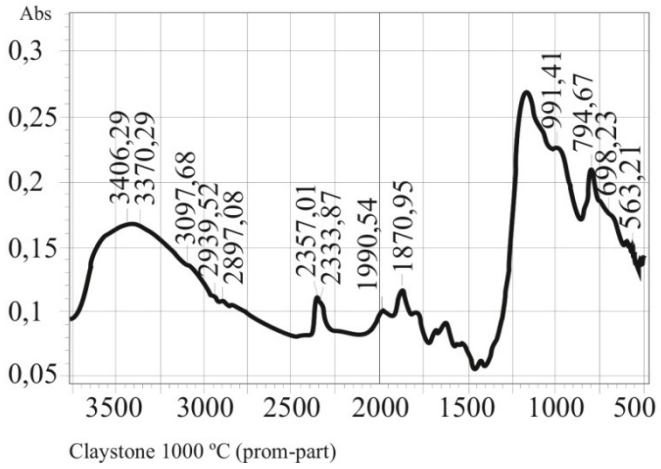


Fig. 5. Infrared absorption spectra of overburnt carbonaceous claylite at 1000 ºC

Absorption bands characteristic of quartz, feldspar, and hematite are fixed in the low- and medium-frequency regions of the spectrum. The pelite structure is identified by the 563, 1170 cm-1 peaks.

One of the most important technological operations in the production of ceramic bricks is mass preparation and shaping. At the forming stage, the coagulation structure is formed, which has certain technological and structural-mechanical properties on which the quality of the finished products depends in the end (Stanevich, et al, 2022; Tkach, et al, 2018; Tleulesov, et al, 2021; Akishev, et al, 2024; Rakhimova,et al, 2024).

To determine the characteristics of elastic-viscoplastic properties of the masses of optimal molding moisture from overburdened rocks crushed to a fraction of less than 0.5 mm, we used a device with parallel-sliding plates, the feature of which is the use as a movement sensor dual diode methanation type 6.MX.5C, the signal from which through an amplifier goes to the potentiometer KSP-4 and strain samples (plates) are recorded on the media (Table 7).

Table 7 - Structural and mechanical characteristics of overburden masses

Feature name	Unit designation	Horizon +50 m		Horizon +100 m		Horizon +150 m	
		Argillite	Siltstone	Argillite	Siltstone	Argillite	Siltstone
1	2	3	4	5	6	7	8
Humidity	ОФВ,%	17,5	17,1	17,5	17,0	16,6	16,3
Modulus of rapid elastic deformation	E_0, МПа	23,4	12,62	12,5	10,04	12,5	11,41

Modulus of slow elastic deformation	E_2, МПа	26,35	14,38	18,51	16,43	10,3	18,26
Notional static yield strength	$P_{K1}*10^{-3}$	0,1	0,14	0,21	0,2	0,24	0,23
Strain rate gradient	$\frac{dE^1}{d\tau}*10^{-4}$	0,39	0,85	1,02	1,18	0,93	0,88
Plastic ductility	η_1*10^8 Па, с	534,2	393,3	470,4	375,6	436,3	351,4
Elasticity	λ	0,48	0,38	0,42	0,34	0,45	0,34
Volarovich plasticity	$\frac{P_{k1}}{\eta_1}*10^{-7}$,$c^{-1}$	0,0022	0,0035	0,0044	0,053	0,057	0,065
True relaxation period	Θ,с	392	578	766	611	772	466
Rapid elastic deformation (elastic)	E_0,%	38	44,8	39,5	45,2	38	47,1
Slow elastic deformation	E_2,%	25,2	24,8	26,0	25,0	27,4	27,6
Plastic deformation	$E_1\tau$,%	36,8	30,4	34,4	29,8	34,6	25,3
Structural mechanical type		III	III	III	III	III	III

Plastic masses must deform without disturbing the continuity and homogeneity and retain their shape after the load is removed. The limiting strength of the structure, at which there is a violation of its cohesion, is the plastic strength (Vyshar, et al, 2023; Girnis, et al, 2024; Bulyga, et al, 2023; Rakhimova, et al, 2023).

To regulate the structural-mechanical properties of masses from overburdened rocks and to improve their coagulation structures, studies were conducted to optimize the fractional composition of masses by the simplex-scheme method of experiment planning, which allowed based on a small number of experiments to obtain a more complete characterization of the studied dependencies and determine the optimal ratio of fractions.

Experiments were conducted for three-component compositions, in which X_1, X_2, and X_3 are taken as the content of particles (%) of size 0,5-0,25; 0,25-0,125; 0,125-0,063 mm, respectively.

The matrix of experiments is given in Table 8.

Table 8 - Matrix for planning experiments

Composition No.	Content (% wt.) fractions, mm		
	0,5 – 0,25 (x_1)	0,25 – 0,125 (x_2)	0,125 – 0,063 (x_3)
1	100	0	0
2	0	100	0
3	0	0	100

4	50	50	0
5	50	0	50
6	0	50	50

The mathematical model of the dependence of structural and mechanical properties on the fractional composition of rocks was expressed by a polynomial of the 2nd order:

$$y = b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3$$

Where y is the parameter under study;
y_i - experimental values;
b_i - empirical coefficients.

On a cone plastome, at a constant speed of immersion of the cone - 3 minutes and increasing loads according to the scheme: 20, 70, 120, 170, 220, 270, 320 g studied the relationship between the plastic strength and moisture of the masses of overburden rocks of different fractional composition. The research aimed to clarify the nature of the relationship between the value of plastic strength and moisture content of masses of argillite and siltstone horizons +50, +100, and +150 m, crushed to different fractions (Figure 6).

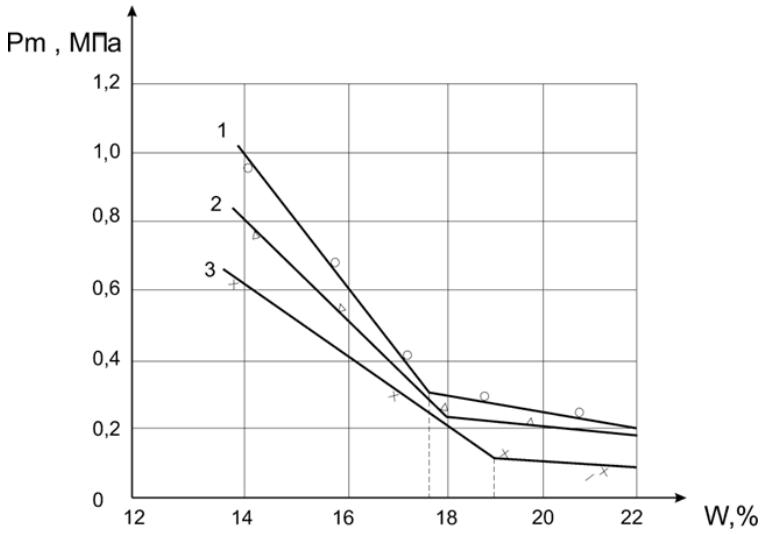


Fig. 6. Curves of dependence of plastic strength on humidity of masses from argillite of horizon +100 m: 1-fraction 0,5-0,25 mm; 2-fraction 0,25-0,125 mm; 3-fraction 0,125-0,063 mm.

Thus, the masses of rocks milled to a fraction of 0,5-0,25 mm are characterized by low development of plastic properties due to insufficient hydration, high strength, high energy consumption for processing, and belong to satisfactorily

moldable. Masses of rocks of fraction 0,25-0,125 mm are well formed, sufficiently homogenized, and insensitive to deformation during drying. Masses of rocks of fraction 0,125-0,063 mm are characterized by high humidity, and sensitivity to drying.

Taking into account the granulometric composition of the coal waste and based on the previously selected optimal fractional compositions of overburden rocks of different lithological types and horizons of occurrence, a series of samples-cylinders 50 mm in diameter and 45-55 mm in height were molded. Optimal fractional compositions of ceramic charge materials are shown in Table 9.

Table 9 - Optimal fractional composition of overburden rocks of coal mining

Name raw materials	Content of overburden, in % for the fraction size, mm		
	0,5-0,25	0,25-0,125	0,125-0,0063
Argillite	5-45	10-55	15-50
Siltstone	10-55	15-50	15-45

The molded samples were kept in natural conditions for one day and then dried in a desiccator for 24 hours at a maximum temperature of 90±5 °C. After drying, the samples were inspected and all changes in appearance were recorded, and air shrinkage and other characteristics were determined. The firing was performed in a laboratory furnace with automatic control of the firing mode with an average temperature rise rate of 1-3 deg/min and held at the maximum temperature of 1,5-2 hours according to the established mode at a temperature of 1000 °C.

It is possible to control the structure and properties of masses in the process of their processing by introducing various additives, which help to change the structural and mechanical properties of masses within a wide range. Positive effects on molding and structural-mechanical properties of the masses have organic and plasticizing additives (Ryzhkov, et al, 2021; Maussymbayeva, et al, 2024).

The influence of high-mineralized coal rocks and high-base technical aluminum oxychloride on the quality indicators of products from overburdened rocks of coal mining was studied.

Highly mineralized carbonaceous rocks were previously ground to a fraction of less than 0.125 mm and introduced into the mixtures in an amount of 4-12% (compositions 1-3, Table 11).

The introduction of carbonaceous rocks containing resin and bituminous substances allowed to decrease in plastic viscosity of the masses by 6-13 %, which improved the mobility of the masses, decreased plastic strength by 18-23 %, which reduced rigidity and favorably influenced the molding ability of the masses.

The use of highly mineralized carbonaceous rocks allowed for to improvement of molding properties of the masses, to decrease water absorption of products, as well as to increase their physical and mechanical characteristics (Table 11). Aluminum oxychloride composition corresponds to the formula [Al(CH)3-XClX] n, where X = 0.5; n = 2.

Raw mixes of overburdened rocks crushed to fractions less than 0.5 mm were moistened with water mixed with aluminum oxychloride in an amount of 3-7% to normal molding moisture (composition 4-6, Table 10).

Table 10 - Compositions of raw mixes containing solid and liquid additives

Components	Content of components in the mixture, mass %					
	1	2	3	4	5	6
Overburden rock from coal mining	96	92	90	97	95	93
Highly mineralized coal-bearing rocks with 3-9% resin and bituminous substances	4	8	12			
Highly basic technical aluminum oxychloride				3	5	7

When studying the effect of aluminum oxychloride on the structural and mechanical properties of overburden masses, it was found that the mechanism of aluminum oxychloride effect is identical for all lithological rock types and does not depend on the depth of their occurrence.

The aluminum oxychloride inclusion helps to improve the molding and rheological properties of the masses by reducing their plastic viscosity by 40% and plasticity strength by 20-25%. Indexes of plasticity of these masses 0,48-0,66 are close to values typical for well forming masses. There is a redistribution in the ratio of deformations in the direction of the prevailing development of deformations, which indicates that the masses belong to the first structural-mechanical type.

The results of determining the physical and mechanical properties of the obtained products are shown in Table 11.

Table 11 - Results of physical and mechanical tests

№	Component content in mass, %			Compressive strength, MPa	Water absorption,%	Frost resistance, cycle
	Overburden	carbonaceous rock	Aluminum oxychloride			
1	96	4		42,0	10,8	58
2	92	8		48,2	9,2	72
3	88	12		44,0	9,6	64
4	97		3	34,2	8,2	62
5	95		5	33,6	7,4	63
6	93		7	36.4	7.0	68

The influence of aluminum oxychloride on the physical and mechanical parameters of the obtained products is manifested in the reduction of water absorption from 8.2 to 7.0 %, and an increase in compressive strength by 10-12 %. Products containing aluminum oxychloride can withstand 100 cycles of alternate freezing and thawing and have a good appearance.

Conclusion. Based on the conducted research, the following conclusions can be made:

- overburden rocks according to the standards of radiation safety can be used for

the production of all types of building materials without restrictions, the number of potentially toxic elements in the waste does not exceed the maximum permissible concentrations, which characterizes them as environmentally safe raw materials;

- according to chemical and mineral composition and the content of water-soluble salts, coal mining wastes are close to clay raw materials and belong to the group of semi-acidic with low content of dye oxides of raw materials;

- it is established that having a high degree of metamorphism, overburdened rocks are not soaked in water and show the ability to plastic formation when breaking their condensation and cementation bonds by grinding to a fraction of less than 0.5 mm. The rocks ground to the specified fraction is moderately plastic and insensitive to drying.

- improvement of structural and mechanical characteristics of masses from overburdened rocks of coal mining is achieved by using highly mineralized carbonaceous rocks and aluminum oxychloride as organic and plasticizing additives. The products received with the use of additives have compressive strength 33,6-48,2 MPa, frost resistance 50-100 cycles, and water absorption 7,0-10,8.

Overburden rocks of coal mining are close to the traditional clay raw materials in physical and mechanical properties, chemical and mineral composition, and can, with appropriate technological preparation and the introduction of additives, be used for the production of ceramic bricks.

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