



UDC 658.567.1

ASSOCIATED ROCKS OF COAL MINING AS A RAW MATERIAL FOR THE PRODUCTION OF TECHNICAL MATERIALS

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Received 22 December 2026; accepted 28 January 2026; available online 20 June 2026

Abstract

The relevance of the work is related to solving environmental problems while reducing the use of natural resources and finding ways to create binders using industrial waste as raw materials. The research objective of the work is to investigate the petrographic and hydraulic characteristics of waste rock from the Khmel'nitska and Sverdlov mines in the Luhansk region and to explore the potential for their use in the production of construction materials. The elemental composition of waste heap rocks was determined using INCA electron probe microanalysis. Petrographic studing of the samples was carried out using a MIN-8 and Nu-2E microscope in transmitted light in transparent sections. The hydraulic activity of the waste rocks was determined by the amount of absorbed lime CaO. In order to study the behavior of minerals and the amorphous phase of waste rocks at high temperatures, for example, under the conditions of the cement clinker production, sintering was carried out at $t_{\max} = 1580\text{ }^{\circ}\text{C}$ for 10 h in an oxidizing medium of O_2 and CO_2 . The studied rocks contain amorphous phases and a crystalline part, in which minerals muscovite, quartz, and clinocllore are presented. The rocks are classified as ultra-acidic. Sintered coal rocks consist of a glass phase in which are distributed crystals of minerals: ferruginous spinels, mullite, and pyroxenes (diopside and hedenbergite), which were formed by high-temperature reactions. The possibility of using coal mining rocks in cement production is confirmed by the similarity of their oxide compositions. The high Fe_2O_3 content promotes the formation of a melt, in which lime reacts better with other minerals. The combined presence of Al_2O_3 and Fe_2O_3 leads to the formation of Ca aluminoferrites with an increased aluminate content. The high content of the glass phase, the presence of Al_2O_3 and Fe_2O_3 , and the excellent hydraulic properties of the rocks make them suitable for use in the production of lime-slag binders, aluminous cement, and as corrective or active additives to Portland cement clinker. By introducing rocks before sintering the raw material mixture, the M_{al} and $M_{c.f.}$ modulus can be adjusted.

Key words: coal mining rock; petrographic analysis; hydraulic activity; modulus classification; building materials.

СУПУТНІ ПОРОДИ ВУГІЛЬНОГО ВИДОБУВАННЯ ЯК СИРОВИНА ДЛЯ ВИРОБНИЦТВА ТЕХНІЧНИХ МАТЕРІАЛІВ

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Анотація

Актуальність роботи пов'язана з вирішенням екологічних проблем у ході скорочення використання природних ресурсів та пошуком шляхів створення в'язучих речовин з промислових відходів. Метою дослідження є вивчення петрографічних та гідралічних характеристик пустих порід шахт Хмельницької та Сverdlova Луганської області та вивчення потенціалу їх використання в виробництві будівельних матеріалів. Елементний склад відвальних порід визначався за допомогою електронно-зондового мікроаналізу INCA. Петрографічне вивчення зразків проводилося за допомогою мікроскопів MIN-8 і Nu-2E у прохідному світлі на прозорих шліфах. Гідралічна активність пустих порід визначалася кількістю поглиненого вапна CaO. Для вивчення поведінки мінералів та аморфної фази пустих порід за високих температур, наприклад, в умовах виробництва цементного клінкеру, проводилося спікання за $t_{\max} = 1580\text{ }^{\circ}\text{C}$ протягом 10 год у окиснювальному середовищі O_2 та CO_2 . Досліджені породи містять аморфні та кристалічну фази: мінерали мусковіт, кварц і клінохлор, які класифікують як ультракислі. Спечені вугільні породи складаються зі скляної фази, в якій розподілені кристали мінералів: залістих шпінелей, муліту, піроксенів (діопсиду та геденбергіту). Можливість використання вугільних порід у виробництві цементу підтверджується подібністю їх оксидного складу. Високий вміст Fe_2O_3 сприяє утворенню розплаву, в якому вапно краще реагує з іншими мінералами. Присутність Al_2O_3 і Fe_2O_3 приводить до утворення алюмоферитів Ca зі збільшеним вмістом алюмінату. Високий вміст склофази, наявність Al_2O_3 та Fe_2O_3 , висока гідралічна активність порід роблять їх придатними для використання в виробництві вапняно-шлакових в'язучих речовин, глиноземистого цементу та як коригувальних або активних добавок до портландцементного клінкеру. Вводячи породи в сировинну суміш до її спікання, можна регулювати глиноземистий та глинітно-залістий модуль.

Ключові слова: гірська порода вугільної промисловості; петрографічний аналіз; гідралічна активність; модульна класифікація; будівельні матеріали.

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© 2026 Oles Honchar Dnipro National University; doi: 10.15421/jchemtech.v34i2.347538

Introduction

To comply with the concept of sustainable development, industrial and agricultural enterprises strive to find useful properties in low-toxic waste, associated rocks, and other types of waste for their disposal. This ensures the economical use of minerals. Improvement of the ecological and agrochemical state of soils can be achieved through the use of natural minerals [1]. Simultaneously, the hydrophysical properties of soils are optimized. Soil fertility increases with an increase in the proportion of available phosphorus. A similar effect is achieved with the combined application of mineral fertilizers and aluminosilicate clays to soils [2]. Industrial waste that has undergone thermal treatment, oxidation and modification of the surface structure often exhibit sorption activity [3]. The feasibility of using blast furnace slag dumps for obtaining slag-alkali binders has been proven [4]. Identification of components in waste with technically useful properties and consumer appeal is relevant. Due to this, the number of dumps and tailings ponds can be reduced, and the volumes of recycling and transformation of associated rocks can be expanded [5].

The construction materials industry has long used various industrial waste as a substitute for primary raw materials. Eliminating the accumulation of recyclable waste and using it as a raw material source ensures recycling in accordance with the concept of a circular economy [6]. Coal and rock mining yields large volumes of host and overburden rock, which replenish waste heaps and spoil heaps [7; 8]. Coal mining overburden is used in the construction of temporary quarries and access roads. High shear strength and static modulus of elasticity are the main indicators for determining the effective particle size distribution of filler [9]. An environmentally friendly way to utilize coal and mining waste is to use it in brick production [10]. Improved brick properties are achieved with certain process parameters and component ratios. Coal mining waste can serve as a raw material component in cement production [11]. The resource value of burnt coal mining rocks, which contain highly active modifications of Si, Al, and Fe oxides, has been substantiated [12]. These rocks are characterized by high hydraulic activity, which allows for their utilization as a pozzolanic-clay additive to cement clinker or as a microfiller in asphalt binders.

The main components of coal mining waste are inorganic substances (80–90%), the rest are organic compounds. Inorganic substances can be

in both crystalline and amorphous states. The main factor determining the state of the substance is the firing temperature in the waste heaps. Spontaneous combustion of waste heaps occurs as a result of the oxidation of organic compounds and self-heating of rocks. The degree of thermal transformation of substances is determined by the duration and rate of firing, heating temperature, and oxygen access [13; 14]. Rocks from the waste heaps of the Eastern Donbass in the form of argillite-like clays, argillites, shales, and siltstones are used in the production of wall ceramics [15]. High-quality bricks with high physical and mechanical properties are made from argillites. A mixture of coal enrichment waste, coal mining waste, clay minerals, and dolomite screenings in a ratio of 1:1–1:2 served as raw material for the production of hydraulic lime [16]. Certain types of inert waste from coal mining and its processing can be used as raw materials for the production of pozzolanic cements [17]. Also, waste from the coal mining industry is a concentrator of natural radionuclides and can pose a certain danger. Therefore, radioecological monitoring of industrial waste used as raw materials is relevant [18].

The particle size distribution of waste largely determines its mineralogical and elemental composition. The chemical composition of coke varies with its particle size, and the petrographic composition of the coal charge is the determining factor [19]. Therefore, a final conclusion on waste utilization can be made only after studying average samples and individual particle size fractions.

The method for determining the resource value of industrial waste for its recycling as technical materials [20] optimizes the systematic nature of research, increasing its comprehensiveness and effectiveness. A combination of research methods enables the determination of the mineral, elemental and radionuclide composition of industrial waste, its surface structure, sorption, hydraulic activity, and the behavior of minerals upon heating. A comprehensive study of the properties of various coal mining wastes will allow the development of recommendations for their practical use in binder production technologies.

The research objective of the work is to investigate the petrographic and hydraulic characteristics of waste rock from the Khmel'nitska and Sverdlov mines in the Luhansk region and to explore the potential for their use in the production of construction materials.

Experimental methods of the research

Sampling was carried out in accordance with recommendations [21; 22]. Sampling from the conical embankment was carried out as follows: seven point samples were taken along the cone's perimeter at approximately equal intervals at a height of 0.8 m. Each point sample weighed approximately 2 kg. A composite sample was created from the point samples, from which an average laboratory sample was obtained by quartering.

The elemental composition of waste heap rocks was determined using INCA electron probe microanalysis on a JSM-820 scanning electron microscope, which was used to calculate the oxide composition.

Petrographic studying of the samples was carried out using a MIN-8 and Nu-2E microscope in transmitted light in transparent sections.

The hydraulic activity of the waste rock was determined by the amount of absorbed lime CaO [23].

In order to study the behavior of minerals and the amorphous phase of waste rocks at high temperatures, for example, under the conditions of the cement clinker production, sintering was carried out at $t_{\max} = 1580\text{ }^{\circ}\text{C}$ for 10 hours in an oxidizing medium of O_2 and CO_2 .

The reliability of the results is confirmed by their reproducibility when conducting 3 repeated measurements using each research method.

Results and discussion

Mineralogical and oxide composition of waste rock. According to X-ray phase analysis, several minerals are present in the crystalline portion of the waste rock [12]:

- quartz SiO_2 ;
- clinochlore $(\text{Mg,Fe})_6(\text{Si,Al})_4\text{O}_{10}(\text{OH})_8$;
- muscovite $\text{K}_{0.94}\text{Na}_{0.06}\text{Al}_{1.83}\text{Fe}_{0.17}\text{Mg}_{0.03}(\text{Al}_{0.91}\text{Si}_{3.09}\text{O}_{10})(\text{OH})_{1.65}\text{O}_{0.12}\text{F}_{0.23}$.

In descending order of mass content, minerals can be arranged in the order muscovite > quartz > clinochlore. Clinochlore and muscovite are clay minerals that can be used in the production of Portland cement clinker [24].

The wavy nature of the obtained diffraction patterns indicates the presence of compounds in an amorphous state. A general picture of the elemental content in the crystalline and glassy states was obtained using X-ray microanalysis of the samples, the results of which for the non-carbon portion of the rock are presented in Table 1. The remaining rock is composed of carbon, indicating a low degree of rock firing in waste heaps.

Based on the elemental analysis data, the oxide composition of coal rocks was calculated and presented in Table 1.

Table 1

Mass fraction (%) of element oxides in the non-carbon part of waste rocks and their classification according to the modulus system

Oxide	Waste rock from the Sverdlov mine		Waste rock from the Khmel'nitska mine after sintering
	before sintering	after sintering	
Na_2O	0.60	1.10	0.67
K_2O	4.82	3.06	3.55
MgO	1.53	1.10	2.54
CaO	1.62	2.21	–
SiO_2	50.97	42.74	66.88
Al_2O_3	22.08	39.56	21.78
SO_3	4.85	–	–
Cl_2O	0.06	–	–
TiO_2	1.20	0.60	0.71
FeO	10.96	9.63 (Fe_2O_3)	3.87 (Fe_2O_3)
CuO	1.12	–	–
MnO	0.19	–	–
Modulus			
$M_a = \frac{\text{Al}_2\text{O}_3}{\text{SiO}_2}$	0.43	0.93	0.33
$M_s = \frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$	2.31	1.08	3.07
$M_{al} = \frac{\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3}{\text{SiO}_2}$	2.01	4.11	5.63
$M_{cf} = \frac{\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3}{\text{SiO}_2}$	0.65	1.15	0.38

The obtained results (Table 1) were compared with the data on the oxide composition of clays used as a raw material in the production of Portland cement clinker [25; 26]. In the studied rocks of the Sverdlov mine, the content of Al_2O_3 and Fe_2O_3 is overestimated compared to the data [25]: 1.16–20.28 % Al_2O_3 and 4.04–9.15 % Fe_2O_3 . The content of CaO , MgO , and SiO_2 falls within the recommended ranges. Low content of basic oxides CaO , MgO and high content of acidic oxides SiO_2 and Al_2O_3 indicate the acidic nature of the waste rocks. This situation does not change after sintering. According to the acidity modulus the sintered rocks are classified as ultra-acidic. The SiO_2 content should be $\geq 60\%$ for rocks of this classification group [26]. In the case under consideration, the acidity of the rocks are equally determined by both SiO_2 and Al_2O_3 .

A study of sintered waste rock samples by petrographic method. The molar concentration of SiO_2 determines the structure of silicon-oxygen complexes, acid-base properties, viscosity, and crystallization characteristics of melts. The ultra-acidic rocks studied form acidic melts with a SiO_2 content exceeding that of trisilicate $\text{O}/\text{Si}+\text{Al}+\text{Ti} \leq 2.67$ [26]. With increasing acidity, viscosity sharply increases and the crystallization capacity of silicate melts decreases. Highly viscous acidic melts typically solidify to form glass, as confirmed by petrographic analysis of thin sections.

A sample of sintered rock from the Sverdlov mine is black. The sample is heterogeneous in microstructure and consists of corundum, ferrous spinels (magnetite) and a glass phase (Fig. 1). Corundum is present as isometric, irregularly shaped grains up to 3.2 mm in size (the predominant size is 0.08–0.8 mm). Some grains are corroded and dissected into smaller prismatic and isometric crystals. These prism-shaped corundum crystals are observed in the glass; their length reaches 320 μm and width is 32 μm . The corundum content varies between 15–20 %. The glass is mostly colorless, yellowish, brownish in places, the average refractive index $N_{\text{aver.}} \sim 1.525 \pm 0.005$. The glass contains precipitates of ferruginous spinels similar in composition to magnetite $\text{FeO}\cdot\text{Fe}_2\text{O}_3$ in the form of dendritic, skeletal forms, and idiomorphic crystals 10–40 μm in size, maximum 80 μm . Rare thin acicular crystals of mullite $3\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ up to 150 μm in length are distinguished.

A sample of sintered rock from the Khmelnitska mine is characterized by the presence of black fragments with brown streaks and a glass glitter. The bulk of the sample (Fig. 2)

consists of a glass phase from colorless to yellowish-brownish and to yellowish-greenish in color with $N_{\text{aver.}} \sim 1.535 \pm 0.005$.

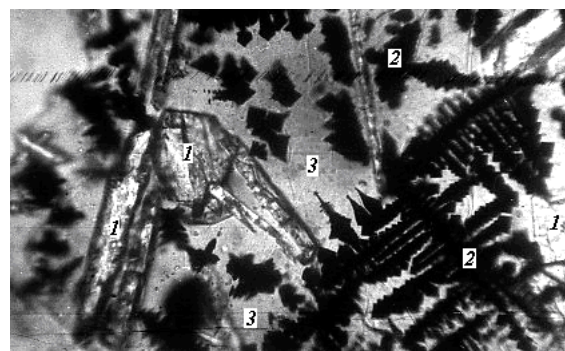
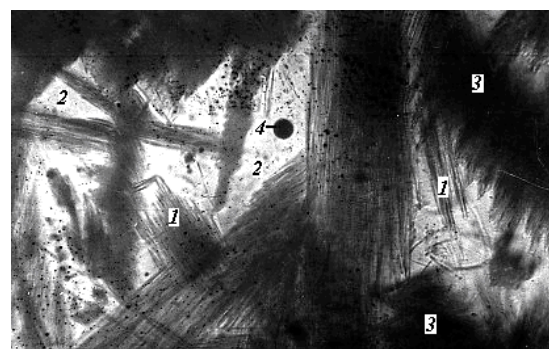
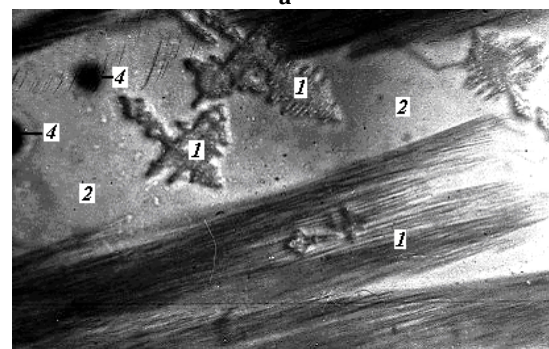


Fig. 1 Sample of sintered rock from the Sverdlov mine: 1 is corundum; 2 is magnetite; 3 is glass phase



a



b

Fig. 2 Sample of sintered rock from the Khmelnitska mine: 1 is mullite (b is dendritic form); 2 is glass phase; 3 is pyroxenes; 4 is metal

The glass contains mullite crystals ($3\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$) of acicular, elongated-prismatic, pinnate, and sometimes subparallel shapes. The crystals are up to 6 mm long (mostly 0.2–1.3 mm) and 4–20 μm wide. Mullite has refractive indices: minimum $N_p \geq 1.658$, maximum N_g up to 1.69. According to the classification of Lodochnikov, relative to the refractive index of Canadian balsam, the studied mullite belongs to the fifth group of minerals according to the N_p , and to the sixth group according to N_g instead of the 5th group with indices $N_p=1.642$ and $N_g=1.654$ [27]. Slightly elevated refractive indices and an average N_g-N_p value of 0.032 (instead of a low 0.012) indicate the presence of a small amount of

Fe oxides in the solid solution. The mullite content in different parts of the slag varies from 5–10 % to 50–60 %.

In some areas, greenish-brownish pinnate pyroxene segregations are observed: diopside $\text{CaO}\cdot\text{MgO}\cdot 2\text{SiO}_2$ and hedenbergite $\text{CaO}\cdot\text{FeO}\cdot 2\text{SiO}_2$. Ferruginous spinels (ranging from herzenite $\text{FeO}\cdot\text{Al}_2\text{O}_3$ to magnetite $\text{FeO}\cdot\text{Fe}_2\text{O}_3$) are also present. Spinel, similar in composition to magnetite, predominate. They form idiomorphic crystals up to 20 μm in size, as well as dendritic and skeletal segregations. Traces (< 1 %) of rounded metallic segregations (Fe), crushed rutile (TiO_2) and hematite grains are also present. The results of the petrographic study of the mine waste rocks after sintering are presented in Table 2.

Table 2

Results of petrographic study of sintered mine waste rocks

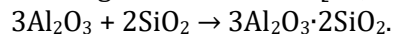
Minerals, phases	Mass fraction, %	
	the Sverdlov mine	the Khmel'nitska mine
Pyroxenes (diopside – hedenbergite)	-	3–5
Ferrous spinels (magnetite)	10–15	5–7
Corundum ($\alpha\text{-Al}_2\text{O}_3$)	30–50	-
Mullite ($3\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$)	traces	30–35
Glass phase	40–60	55–60

The formation of corundum, mullite, and pyroxenes is caused by a series of high-temperature reactions: the thermal decomposition of muscovite and clinocllore, the formation of elemental oxides with their modification, and reactions between quartz and the resulting oxides. However, there are no reliable data regarding the composition of the high-temperature phases of clayey mineral mixtures. The possibility of the formation of compounds other than those resulting from the roasting of individual minerals as primary phases is recognized [24].

Heating to 800 °C causes muscovite to gradually release water, while the mineral lattice expands. The crystal structure collapses between 940 and 980 °C. At 1000 °C, $\gamma\text{-Al}_2\text{O}_3$ and a small amount of spinel are formed from muscovite grains. $\alpha\text{-Al}_2\text{O}_3$ appears at 1200 °C [24]. The type and number of polymorphic forms of Al_2O_3 depend on the temperature, sintering duration, and the presence of modifying impurities (Fe). The number of point defects in the crystal

structure of Al_2O_3 and its chemical activity increase in the presence of Fe(II) and Fe(III) ions.

The formation of secondary mullite can occur during sintering from the formed oxides in the temperature range 1100–1410 °C [28, 29]



Magnetite $\text{FeO}\cdot\text{Fe}_2\text{O}_3$ is formed at 1400–1600 °C in the sequential reactions hematite \rightarrow maghemite \rightarrow magnetite. At temperatures above 500 °C, Fe oxides undergo thermal dissociation with loss of oxygen [24]. Diopside is obtained by sintering and melting the resulting mixture of lime-magnesia and silica materials.

The potential use of waste rock as a prospective mineral resource. The discovery of high concentrations of mica and chlorite minerals in mine waste is valuable. World mica resources are unknown and uncertain for the future. The high cost of mica and the difficulties in prospecting for and exploration of new deposits lead to its replacement with synthetic materials. For the studied rocks, abundant quartz inclusions, high Fe content, and fragmentation of mica plates reduce the applicability of mica as an electrical insulating material in electrical and radio engineering.

The significant Al_2O_3 content (up to 40 %) in the sintered rock sample from the Sverdlov mine makes it possible to use the waste rock as raw material for the production of refractories. The refractoriness of the sintered rocks, calculated using the formula [30]

$$C = \frac{360 + \text{Al}_2\text{O}_3 - \text{RO}}{0.228},$$

falls within the range from 1660 to 1738 °C, which meets the requirements for refractory materials (≥ 1580 °C). A negative factor is the presence of Fe oxides, which are undesirable impurities in refractory production. The microstructure of a sintered rocks differs from that of a refractory. Sintered samples contain a large amount of glass phase. In the structure of the refractories, thin layers of glass phase are located between well-crystallized grains of the solid solution of corundum in mullite [31].

Mine waste rock of varying degrees of firing is traditionally used as a component of building mortars, as raw material for the production of clinker bricks, agloporite and hydraulic binders [32]. The studied rocks cannot be used as a concrete filler due to the presence of unburned coal [33].

The hydraulic activity of a rock was determined by the amount of absorbed lime CaO. For this purpose, a crushed sample of an average

mine rock (10 g) was soaked in a CaO solution with an initial concentration of 5.63 %. The CaO concentration was monitored over time during interaction with the rock. The experimental results are presented in Table 3.

Table 3

Activity of waste rock for CaO absorption				
Mine rocks	Contact time of the rock with the CaO solution	CaO content in solution, %	Absorption of CaO, %	Sorption capacity of rock, mg/g
the Khmel'nitska mine	1 day	3.0	2.63	261.2
	3 days	2.0	3.63	360.7
the Sverdlov mine	1 day	3.63	2.0	199.0
	3 days	3.0	2.63	261.2

A comparison of the obtained data with those available in the literature shows that the value of CaO absorption is high and exceeds those for burnt rock (30 mg/g for 30 days) and siliceous, ferruginous burnt rocks of Kuzbass (40–130 mg/g of lime) [34]. The values of lime absorption were determined for a shorter period (3 days), which must be taken into account when comparing with the literature data. The absorption capacity of the studied mine rocks is comparable to the quantitative indicators for acidic hydraulic additives: tripoli and diatomite (250–400 mg/g) [25]. High absorption capacity indicates significant hydraulic activity. Mine rocks can be used as active additives to cement clinker, which should absorb at least 50 mg/g of lime in 30 days [25].

The hydraulic activity of rocks is determined not only by the oxide content but also by their ratios described by a modulus system. Some of these modulus have been calculated and presented in Table 1. According to the activity modulus M_a , the rock from the Sverdlova mine is classified as a Class I acid slag ($M_a \geq 0.4$); the rock from the Khmel'nitska mine is classified as a Class II acid slag ($M_a \geq 0.33$).

To utilize waste in the production of building materials, the silicate modulus M_s should have optimal values of 1.7–3.5. The release of Al_2O_3 oxide after sintering of the Sverdlov mine rock reduces the M_s value to 1.08.

According to the clay-ferrous modulus, ferrous rocks are considered highly active with $M_{c.f.} > 0.49$. According to the results, the most active is the sintered rock from the Sverdlov mine.

The waste rock as raw material for the production of fired binders. The similarity in chemical composition between Portland cement clinker and waste rock makes it feasible for use in cement production. The alumina modulus M_{al} of rocks used in the production of Portland cement clinker should be within the range of 1.0–2.5. The sintered rocks exceed the optimal range. However, several additional factors must be considered: the ability of the raw material to decompose into oxides at relatively low temperatures, the absence of the formation of intermediate compounds that are difficult to decompose, the rate of interaction of the components with CaO, and the potential for reducing energy losses. For example, the low alkali metal and magnesium oxide content of the studied rocks will not predispose to the formation of compounds that hinder the formation of C_3A and C_3S during roasting. Reduced energy losses are predicted for combustion of the carbonaceous portion of the rock in the furnace.

It is assumed that the rate of interaction of CaO with clay rock materials will be higher than with quartz or other rock components [25]. In addition, the high Fe_2O_3 content promotes the formation of a significant amount of melt, in the presence of which lime reacts better with other minerals. The combined presence of Al_2O_3 and Fe_2O_3 will lead to the formation of Ca aluminoferrites with an increased aluminate content. This will reduce the degree of thermal dissociation, which decreases in the series $C_2F > C_6AF_2 > C_4AF > C_6A_2F > C_8A_3F$ [25] and will slow down the decomposition of C_3S observed during the dissolution of FeO in the alite lattice.

When using waste rock as corrective or active additives to Portland cement clinker, they should be added not at the clinker grinding stage, but at a preceding stage to the raw mix, prior to sintering. Corrective additives are introduced to regulate the values of modulus M_s , M_{ab} and $M_{c.f.}$. An additive is necessary when the raw mix is characterized by unfavorable modulus values, or when producing cement clinker with a specific mineralogical composition. By introducing the studied rocks into the raw mix, the M_{al} and $M_{c.f.}$ modulus can be adjusted [35].

A comparison of Al_2O_3 and Fe_2O_3 contents with [24] showed that the Al_2O_3 content is quite high, while the Fe_2O_3 content is lower than in ferrous additives. Therefore, these rocks can be recommended as aluminate-ferrous additives in the production of Portland cement clinker.

The high glassy phase content, the presence of Al_2O_3 and Fe_2O_3 , high M_{al} and M_{cf} values, and the excellent hydraulic properties of rocks also make them suitable for the production of aluminous cement as fired binder. In this case, rock waste can replace blast furnace slags containing calcium and magnesium aluminates with concentrations of up to 45 % Al_2O_3 .

Conclusions

The scientific novelty of the work lies in the fact that, by combining several experimental research methods, a comprehensive assessment of the resource value of unburned mine waste rocks was carried out from the standpoint of

mineralogical and oxide composition, classification according to the system of modules, and hydraulic activity.

The studied coal mine rocks are recommended for practical use as raw materials in the production of aluminate cement and as corrective or active additives in the production of Portland cement. Such corrective additives regulate the values of the aluminate and clay-ferrous modulus of the raw mix.

As a prospect, it is planned to obtain cement clinker using coal mining rocks and study its physical and mechanical properties

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