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STUDY OF RAW MATERIAL RESOURCES FOR THE PRODUCTION OF ALUMINOSILICATE BINDERS UNDER THE CONDITIONS OF THE ARAL SEA REGION

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Abstract
This paper presents a study of local raw materials from the Aral Sea region aimed at producing aluminosilicate binders. The mineralogical and chemical composition, as well as the physical and technological properties of natural resources such as kaolin, limestone, and brick factory waste (chamotte scrap), were examined. The obtained results indicate the potential for efficient use of local mineral resources in the Aral region as a basis for environmentally friendly and economically viable aluminosilicate binders, which contributes to sustainable natural resource management and the development of the region's construction industry.

Keywords: Aluminosilicate binders, Aral region, kaolin, chamotte scrap, mineral raw materials.

Introduction

Aluminosilicate binders (ASB) represent a promising class of inorganic composites formed through the alkaline activation of silicon- and aluminum-containing raw materials. These binders are characterized by high thermal resistance, stability in aggressive environments, rapid strength development, and a reduced carbon footprint compared to traditional Portland cement. Scientific

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interest in ASB is rapidly growing, particularly in the context of sustainable construction and industrial waste utilization.

The synthesis of ASB is based on a reaction between aluminosilicate raw materials (such as metakaolin, fly ash, volcanic ash) and alkaline activators, most commonly sodium hydroxide or aqueous silicate solutions. During this process, amorphous phases dissolve, aluminum and silicon ions are redistributed, and polycondensation occurs, forming a three-dimensional network. Studies show that ASB structure formation can occur both at normal and elevated temperatures, allowing curing conditions to be varied depending on material application [1–3]. A relevant research direction is the optimization of ASB composition to enhance mechanical properties and durability. The addition of carbonate minerals such as calcite promotes the formation of a nanostructured matrix that reduces porosity and improves binding properties [4]. The use of metakaolin, microfillers (such as microsilica or phosphate flour), and complex modifiers allows compressive strengths above 60 MPa to be achieved within 7 days [2, 5, 6].

Research Methods

The research was conducted at Urgench State University, at the Center for Advanced Technologies under the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan, and pilot-scale tests were carried out at "Smart Up Starts" LLC. Modern analytical chemistry methods and instruments were used to study the chemical composition of raw materials, based on the methods described in [7]. The quantities of SiO_2, Al_2O_3, and Fe_2O_3 were determined with an accuracy of ±0.08% according to GOST 5382–2019 [8]. Grain size distribution was determined using sieves in accordance with GOST 12536–2019 [9; 10]. X-ray diffraction (XRD) analysis was performed on a DW-XRD-Y3500B powder diffractometer (power ~3 kW, voltage 10–60 kV, current 5–80 mA, stability ≤0.01%).

Results and Discussion

Our research focused on obtaining aluminosilicate binders, which are typically fine powders consisting of a hydraulically active component and available natural raw materials or industrial by-products used as active mineral additives. Based on

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this, the development and application of ASB can lead to the production of more sustainable composites compared to existing analogues and, in some cases, eliminate harmful environmental effects while ensuring rational use of limited natural resources.

For the synthesis of aluminosilicate binders, the following raw materials were selected: limestone from the Aktau deposit, kaolin from the Chilpik deposit, chamotte scrap from "Dilroz" brick factory, and industrial sodium silicate (liquid glass).

Table Chemical Composition of Raw Materials for Aluminosilicate Binder Production

№	Sample Name	Content (%)										
		SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	SO_3	Na_2O	K_2O	п.п.п.
1	**Chamotte scrap**	60,96	10,85	5,52	0,62	0,35	12,36	3,09	0,69	2,70	1,75	0,34
2	**Limestone**	0,30	0,11	0,08	0,01	0,01	61,13	0,50	0,10	0,03	0,03	37,96
3	**Liquid glass**	22,7-29,6	0,25	0,25	-	-	0,20	-	0,15	9,3-12,8	-	1,36-1,45
4	**Kaolin**	55,33	34,57	0,52	0,33	-	1,32	0,38	0,41	0,66	1,08	5,47

To study the mineral composition of the raw components, X-ray diffraction (XRD) analysis was carried out on kaolin from the Chilpik deposit, limestone from the Aktau deposit, and chamotte waste from JV "Dilroz." Figure 1 shows the X-ray diffraction pattern of kaolin from the Chilpik deposit.

According to the obtained results, the diffraction maxima on the kaolin sample's XRD pattern with interplanar spacings of d = 0.178, 0.256, 0.356, 0.384, 0.424, 0.435, 0.445, and 0.713 nm correspond to kaolinite, while the lines with spacings of d = 0.137, 0.148, 0.154, 0.165, 0.181, 0.197, 0.212, 0.223, 0.227, 0.233, 0.245, 0.334, and 0.424 nm correspond to quartz.

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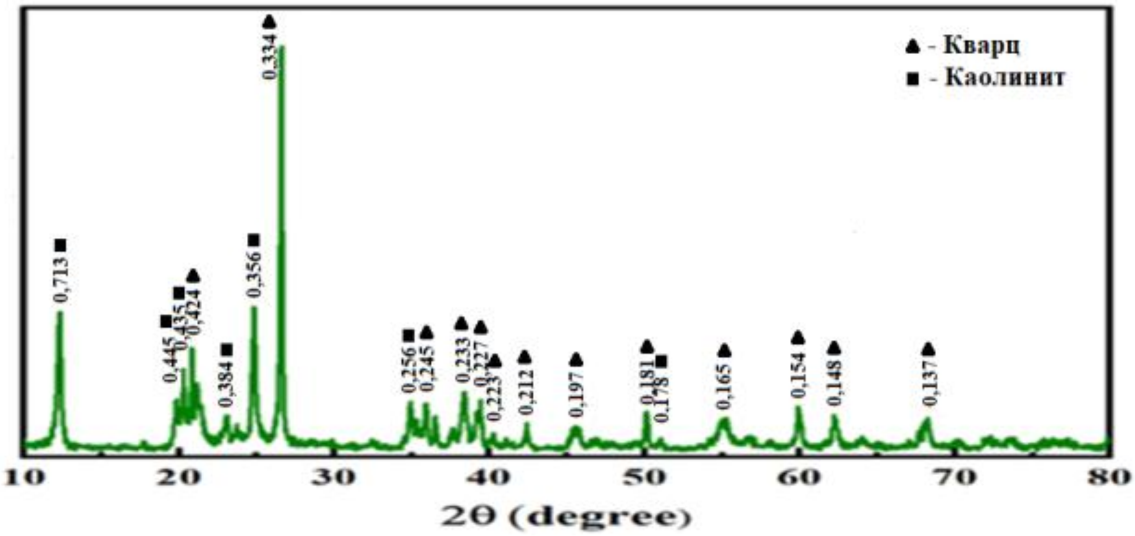

Fig. 1. X-ray diffraction pattern of the raw kaolin from the Chilpik deposit.

Figure 2 shows the X-ray diffraction (XRD) pattern of limestone from the Aktau deposit. According to the obtained results, the diffraction maxima with interplanar spacings of d = 0.154, 0.167, 0.181, 0.212, 0.245, 0.334, and 0.425 nm correspond to the mineral **calcite**. The diffraction lines with spacings of d = 0.187, 0.191, 0.209, 0.228, 0.249, 0.303, 0.319, 0.385, and 0.447 nm correspond to **quartz**, while the diffraction peaks with spacings of d = 0.256, 0.353, 0.376, and 0.402 nm correspond to **aragonite**.

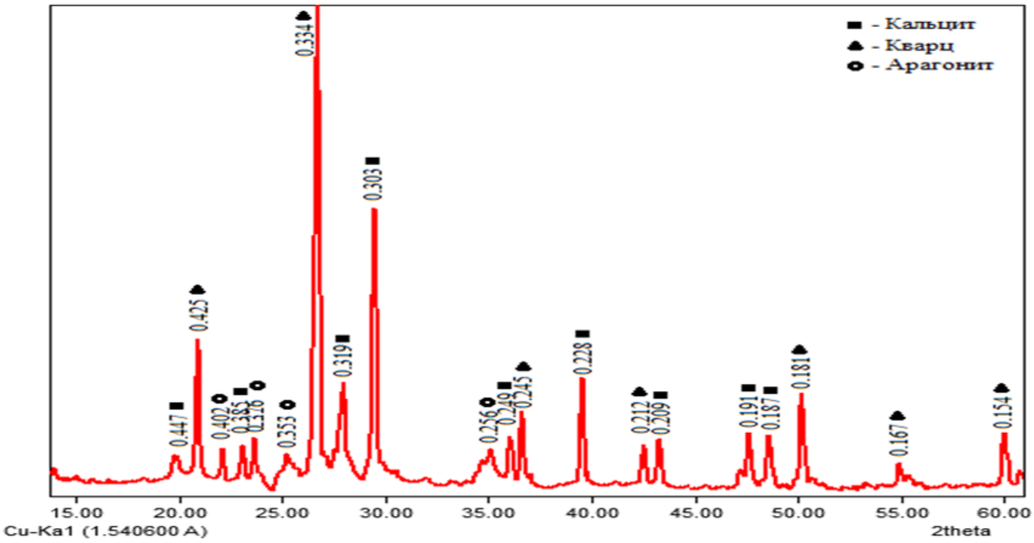

Fig. 2. X-ray diffraction pattern of limestone from the Aktau deposit.

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X-ray diffraction analysis of the crushed ceramic brick (Fig. 3) shows that the examined sample has a typical mineral composition of ceramic materials: the main crystalline phase is **quartz**, while the secondary phases are **mullite** and **hematite**. A significant amount of **amorphous phase** is also present.

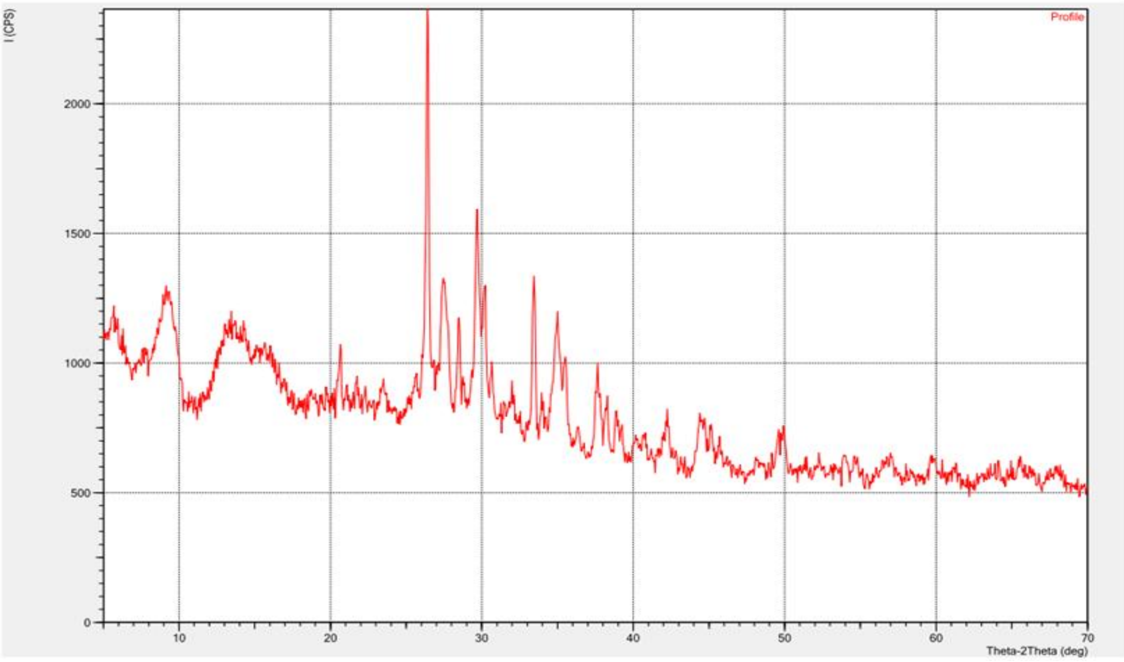

Fig. 3. X-ray diffraction pattern of crushed ceramic brick from JV "Dilroz."

The spectrum shows several distinct peaks in the 2θ range of approximately 20–35°, which is characteristic of crystalline phases present in fired clay materials. The intensity level reaches up to 2200 counts per second, indicating a relatively high degree of crystallinity. The most intense peak is observed at 2θ ≈ 26.5°, which is typical of **quartz (SiO_2)** — the main component of ceramic brick. Peaks in the regions of 2θ ≈ 20–21°, 27–28°, and 31–33° may correspond to **feldspars** (albite, microcline) and **residual muscovite**. Weak peaks at 2θ ≈ 12°, 35–37°, and 41–43° may indicate the presence of secondary phases such as **hematite (Fe_2O_3)**, **anorthite ($CaAl_2Si_2O_8$)**, or **mullite ($3Al_2O_3 \cdot 2SiO_2$)** formed during firing.
On the X-ray diffraction pattern of liquid glass (Fig. 4), a broad amorphous "hump" is observed in the region of approximately 2θ ≈ 15–30°, which is typical of a glassy (amorphous) phase. This is expected for liquid glass (sodium silicate),

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as the main part of the material is in a vitreous state. Against this background, several sharp crystalline peaks are present — the most prominent around 2θ ≈ 28°, followed by smaller peaks in the range of approximately 34–42°. These sharp peaks indicate the presence of crystalline inclusions or impurities within the predominantly amorphous material.

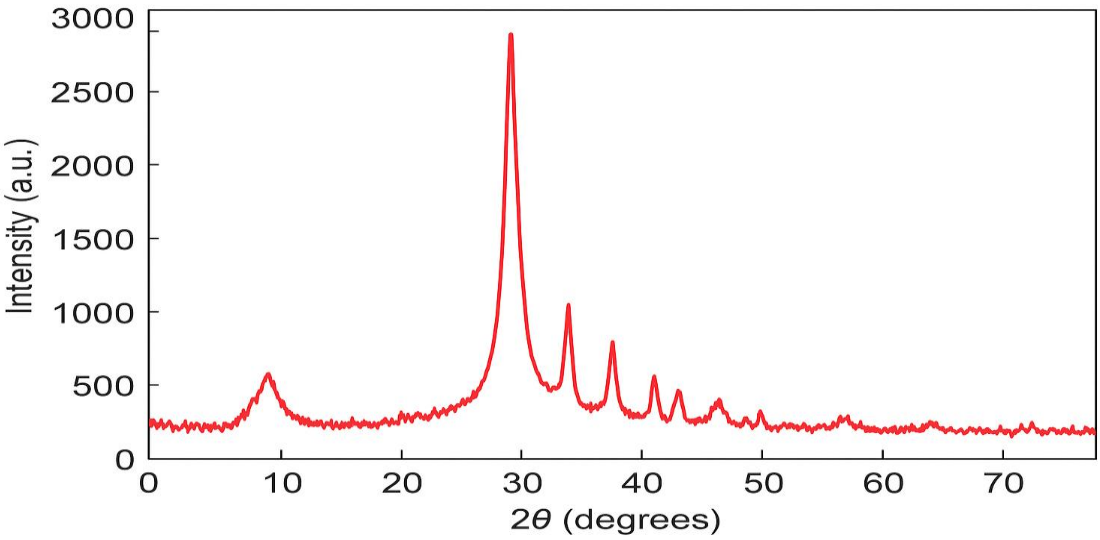

Fig. 4. X-ray diffraction pattern of liquid glass.

Conclusion

The study demonstrated that the mineral raw materials of the Aral region possess high potential for use as the basis of aluminosilicate binders. Chemical and phase analysis revealed a significant content of SiO_2 and Al_2O_3, enabling the formation of zeolite-like and amorphous aluminosilicate structures during thermal activation.

Thus, the use of local natural and industrial raw materials in ASB production is both technologically and environmentally justified. The obtained data serve as a foundation for further research aimed at optimizing composition and synthesis conditions to create strong, durable, and eco-friendly building materials of the new generation.

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