STUDY OF DUNE SANDS OF YAZYAVAN FOR PRODUCING CERAMIC MATERIALS

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ABSTRACT

Results are provided for a comprehensive study of the dune sands of the Yazyavan of the Fergana region to prepare ceramic materials. The research investigates the chemical-mineralogical compositions and physical-chemical characteristics of the dune sands, focusing on their suitability for ceramic production. Various analytical techniques were employed to characterize these sands, including granulometric analysis and X-ray diffraction, to determine the mineralogical composition. The findings reveal that the dune sands possess unique properties that can enhance the quality of ceramic materials when used in combination with other raw materials and industrial wastes available in Uzbekistan. The study emphasizes the importance of optimizing the raw material mix to improve the performance and cost-effectiveness of ceramic products. Additionally, the results contribute to the understanding of local mineral resources and their potential applications in the ceramics industry, highlighting the need for further research to explore innovative ways to utilize these materials effectively. The overall goal is to promote sustainable practices in the production of ceramic goods, leveraging local resources while minimizing environmental impact.

Keywords: ceramic materials, dune sands of Yazyavan, Shursuv bentonite clay, oil sludge, sintering, mineralogical compositions, x-ray phase analysis.

INTRODUCTION

Uzbekistan aims to fulfil its national economic demand for building materials, particularly ceramic-facing tiles and bricks, by increasing production and expanding raw material sources. Non-metallic minerals, specifically rocks, are highlighted as key resources for the ceramic and construction industries. Leveraging Uzbekistan's abundant and promising raw material reservoirs, such as high-silica rocks, is crucial for developing compositions and enhancing production capabilities [1, 2].

In the quest for sustainable and cost-effective materials in the construction industry, alternative sources of raw materials have gained significant attention. Among these, desert sands offer a widely available resource; however, their chemical, mineralogical, and geotechnical properties make them unsuitable for use as fine aggregate in concrete on their own due to poor grading. Despite this, studies have shown that mixing desert sands with well-graded river sand (35 %) can produce satisfactory results for standard load-bearing concrete applications. Research also highlights the potential of utilizing desert sands in the production of pavement bricks, demonstrating positive outcomes for both cost-efficiency and sustainability in construction [3].

Although desert sands lack the optimal properties of conventional aggregates, their performance can be enhanced by blending them with other materials or applying special treatment techniques. For instance, the addition of supplementary materials such as fly ash or slag can improve the mechanical properties of concrete, including strength and durability [4]. This approach not only enhances material performance but also reduces the demand for natural river sand, contributing to the environmental sustainability of the concrete industry.

Furthermore, studies indicate that varying the composition of desert sand can influence crucial properties such as strength, durability, and water absorption in ceramic tile production. Specific compositions of desert sand have been shown to enhance performance, making it a promising sustainable and cost-effective resource for tile manufacturing [5]. By incorporating desert sands with industrial by-products, researchers aim to create eco-friendly and economically viable construction materials. The physical and mechanical properties of these mixtures are analysed to determine their durability and suitability for various construction applications, presenting a viable alternative to traditional materials while addressing industrial waste management challenges [6].

To further this goal, there is an urgent need to develop optimal ceramic body compositions for ceramic materials production using unconventional raw materials from the Yazyavan dune sands, particularly dune sands. Additionally, studying the high temperature sintering processes during firing is essential.

The evaluation of sintering processes involves assessing total linear shrinkage, water absorption, ultimate bending strength, hardness, and heat resistance using standard methods. A series of raw material compositions are prepared to produce ceramic materials based on Uzbekistan's abundant raw material resources, focusing on their primary properties.

The selection of constituent components for ceramic bodies is influenced by the geographical proximity of resources, such as the dune sands of Yazyavan, Shursuv bentonite clay, and oil sludge from the Fergana oil refinery, facilitating efficient production processes.

EXPERIMENTAL

The raw materials and components used in the manufacturing of ceramic mixes for expanded quartz minerals included dune sands from Yazyavan precincts 4 and 5, as well as Shursuv bentonite clay. The 4th section of the Central Fergana deposit (Yazyavan dune sands) is administratively located in the Yazyavan district of the Fergana region, 66 km south-southeast of the city of Fergana. The studied area covers 257 hectares, and currently, the volume of raw materials is 6 562.093 thousand tons. The Shursuv-4 (bentonite clay) deposit is administratively located in the Uzbekistan district of the Fergana region, 17.8 km from the district center, the city of Yaypan, and 7.8 km southwest of the nearest settlement, the village of Shursuv. The industrial reserves of this area amount to 3 583.6 thousand tons. The chemical and mineral compositions of the raw materials used, and test specimen physicochemical properties based upon them were studied using chemical, x-ray (XRD), and infrared (IR) spectrum analysis. The chemical composition of raw materials was determined according to GOST 7031 - 2021 (Table 1). The

Table 1. Dune sands of Yazyavan Chemical Composition.

Sample	mass of oxides, %										
	SiO_2	Al_2O_3	Fe_3O_4*	TiO_2	P_2O_5	CaO	MgO	SO_3	Na_2O	K_2O	LOI**
Precinct 4	62.16	7.14	3.40	0.35	0.29	7.10	4.05	0.30	1.85	2.01	10.86
Precinct 5	42.24	7.42	2.05	0.38	0.08	18.99	3.42	0.10	2.95	3.15	18.51
Precinct 5 (cleaned)	42.66	7.62	2.01	0.30	0.08	18.51	3.63	0.10	3.01	3.12	18.13

**$Fe_3O_4 = FeO + Fe_2O_3$. **Loss on ignition (LOI) includes: hygroscopic water H_2O, water of crystallization, organic and volatile impurities, and CO_2.*

parameters of crystal structures of the dune sands were determined according to the x-ray method, on a wide-angle XRD - 6100 “Shimadzu” (Kyoto, Japan) X-ray diffractometer, monochromated Cu - Ka was used as a radiation source (Gobel mirrors, U = 40 kV, I = 30 mA and scanning speed of 2 deg min^{-1}). In calculations and identification of crystalline x-ray diffraction phases, generally accepted reference data were used [7, 8].

RESULTS AND DISCUSSION

The dune sands of Yazyavan deposit, situated in the Fergana region, encompasses dune sands characterized by sandy rocks varying in hue from light to dark grey. Qualitative characteristics of dune sands of Yazyavan are given in Table 2. These sands exhibit a poly-fractional composition, with particle sizes ranging between 0.10 and 0.52 mm.

Table 2. Qualitative characteristics of dune sands of Yazyavan.

Indicators	Precinct 5	Precinct 4
	Average of indicators	
heterogeneity coefficient, %	1.42	2.33
porosity coefficient, %	0.87	0.9
humidity, %	3.3	4.3
content of organic impurities, %	0.43	0.43
soil particle density, g cm^{-3}	2.7	2.7
soil density at humidity	1.49	1.79
skeletal density	1.44	1.42
content of soluble salts, %	0.44	1.2
sulfate ion content, mg kg^{-1}	5120	7770

From the preliminary analysis of the samples taken from the sands of the dune sands of Yazyavan, it was found that the raw materials in the precinct 5 contain a large amount of calcite and dolomite, including feldspars, which affect the melting temperature. Therefore, samples were taken from the precinct 4, their roentgenograms were compared, and the mineral phases in the composition were studied (Fig. 1).

X-ray diffraction analysis of the dune sands reveals distinct diffraction lines corresponding to various minerals present within the sample. Notably, diffraction patterns indicate the presence of quartz (d = 0.425, 0.334, 0.182, and 0.154 nm), calcite (d = 0.303, 0.249, and 0.209 nm), dolomite (d = 0.288 and 0.177 nm), albite (d = 0.320, 0.325, and 0.640 nm), potassium feldspar (d = 0.324 and 0.279 nm), and muscovite (d = 1.004, 0.498 and 0.346 nm). These findings shed light on the mineralogical composition of the dune sands of Yazyavan, providing valuable insights for further research and industrial applications.

The alkaline-earth bentonite clay sourced from the Shursuv deposit, situated in the Fergana region, consists of clayey rocks exhibiting light to dark brown colour. X-ray phase analysis conducted on the clay extracted from the Shursuv bentonite clay reveals the presence of distinct diffraction lines corresponding to various minerals. Notably, the study indicates the presence of quartz, with characteristic peaks observed at d = 0.426, 0.334, 0.245, 0.181, and 0.166 nm, confirming its significant contribution to the mineral composition. Additionally, the high-ferrum form of hematite is identified, with diffraction peaks appearing at d = 0.270, 0.228, and 0.145 nm. Hematite’s high thermal stability enhances the clay’s potential for high-temperature industrial applications. The analysis further identifies chlorite, a layered silicate mineral, with peaks at d = 0.711 and 0.355 nm. Chlorite is known for its excellent thermal stability and structural integrity, making it suitable for use in high-temperature and chemically resistant applications. In addition, illite, a mica-based clay mineral, is confirmed with peaks at d = 0.980, 0.752, 0.501, 0.446, and 0.379 nm. Illite’s unique crystal structure improves the clay’s plasticity and ion exchange capacity, making it highly valuable in industrial processes. The study also reveals the presence of albite, a feldspar mineral, with diffraction peaks observed at d = 0.416, 0.281, and 0.212 nm. Albite significantly contributes to the clay’s overall chemical stability and thermal properties, especially in ceramic fluxing processes. Finally, calcite, a carbonate mineral, is identified with diffraction peaks at d = 0.304, 0.281, and 0.145 nm. Calcite plays a notable role in enhancing the mechanical and thermal properties of ceramic and construction materials, further emphasizing the clay’s

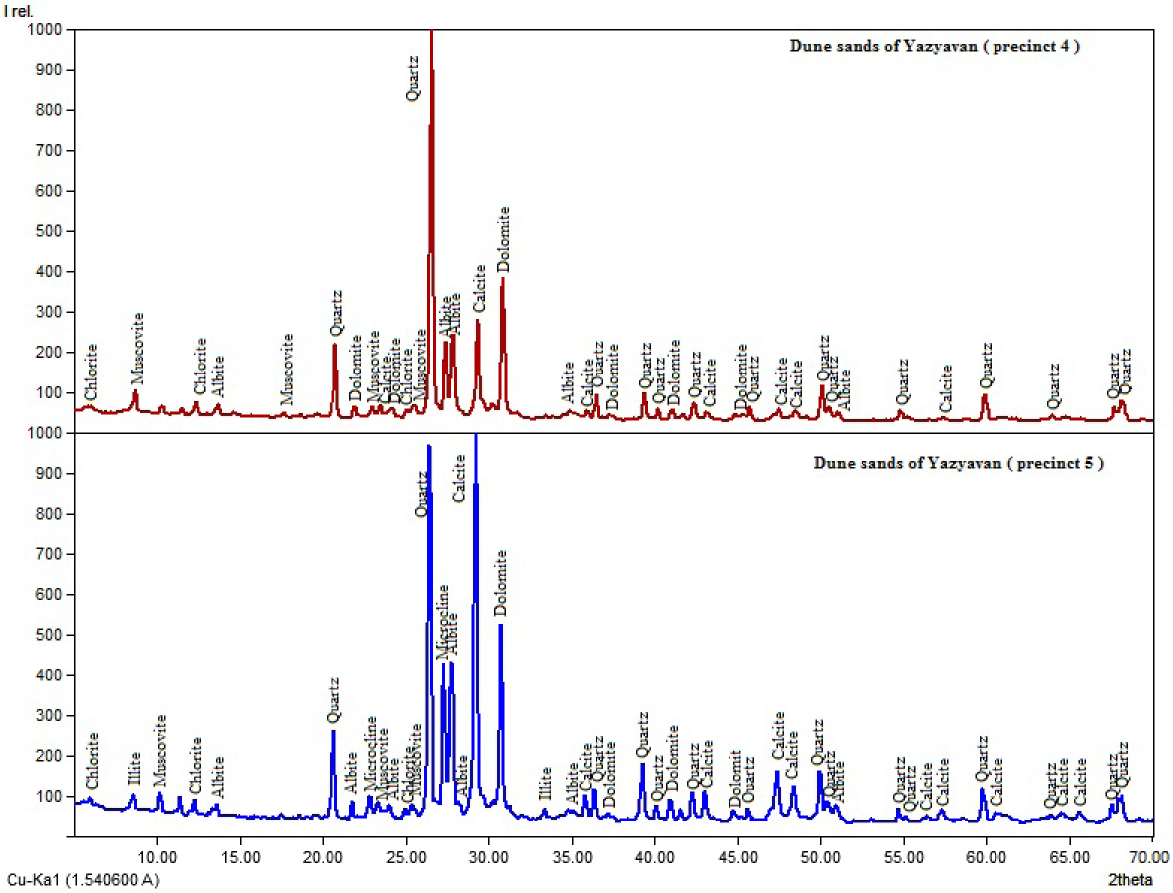

Fig. 1. Dune sands of Yazyavan.

industrial value. These findings provide comprehensive insights into the mineralogical composition of the Shursuv bentonite clay, highlighting its complex mixture of minerals, including quartz, hematite, chlorite, illite, albite, and calcite. This diverse composition underscores the potential of this resource for industrial applications such as ceramics, adsorbents, and other high-performance materials.

We previously discussed the elemental composition and infrared analysis of oil sludge, which is industrial waste, and the X-ray image obtained from the residue after incineration at 650°C [9]. For this reason, in this work, we focused on the selection and analysis of a specific section of the dune sands of Yazyavan. From this point of view, IR spectra of dune sands were taken and compared. In addition, the sample of precinct 4, which was found to be chemically suitable for use, was burned at a temperature of 1000°C for 2 h, and the spectrum obtained from it was also analysed (Fig. 2).

Minerals identified in XRD were also studied in the IR spectrum. In particular, it was confirmed that the absorption frequencies are 1146, 785 - 788, 776, 695, 452, cm^{-1} in quartz [10], 1003, 1006, 609 cm^{-1} in albite, 1088, 1012, 644, 587, 464, cm^{-1} in microcline [11], 521, 428 cm-1 in illite [12], 797 cm^{-1} in muscovite [13], 657, 448 cm^{-1} in chlorite [14], 1420 - 1437, 874 - 877, 712 cm^{-1} in calcite [15] and 728 - 733 cm^{-1} in dolomite [16].

Elemental analysis confirmed the following composition (mass %): C - 13.6, O - 47.6, Na - 1.11, Mg - 1.54, Al - 4.40, Si - 18.66, S - 1.03, K - 1.65, Ca - 8.23, Ti - 0.19, Fe - 1.98.

Oil sludge is liquid and contains approximately 5 % mechanical impurities. Adding 5 % of this sludge to the ceramic leaves almost no dry residue. During combustion, the liquid organic component aids in the uniform burning of the ceramic material. During firing, the organic fraction contributes to the sintering process by enhancing uniform heat distribution, while the

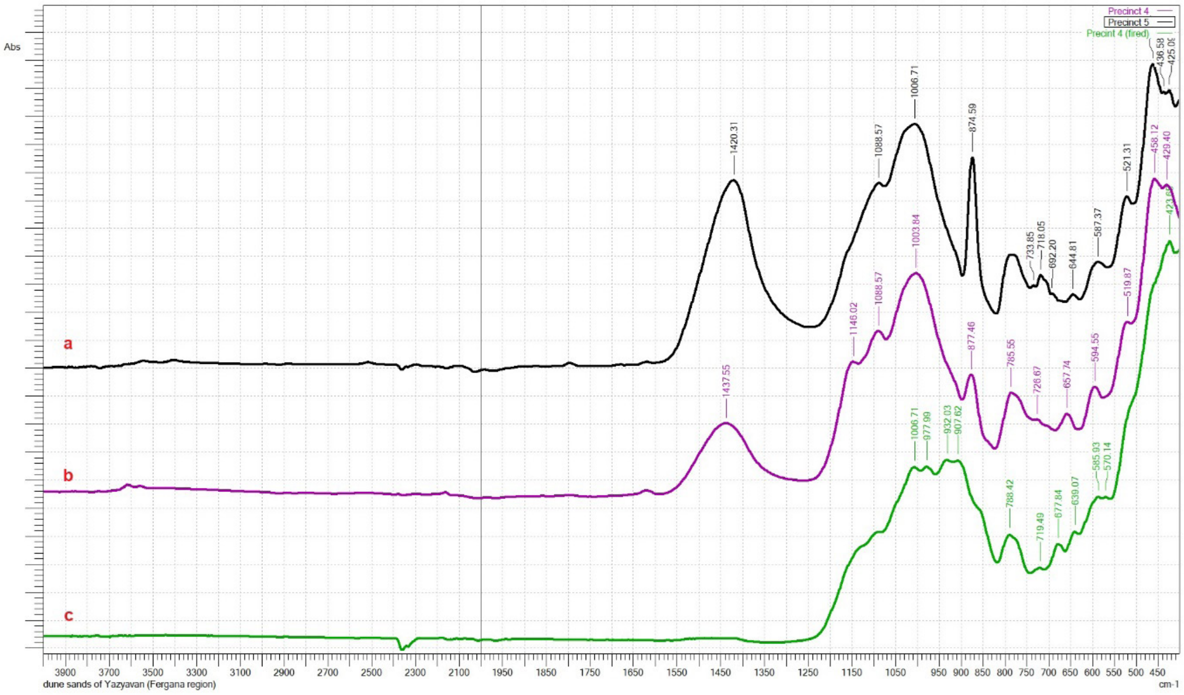

Fig. 2. IR spectrum dune sands of Yazyavan: (a) precinct 5;(b) precinct 4; (c) precinct 4 (fired at 1000°C).

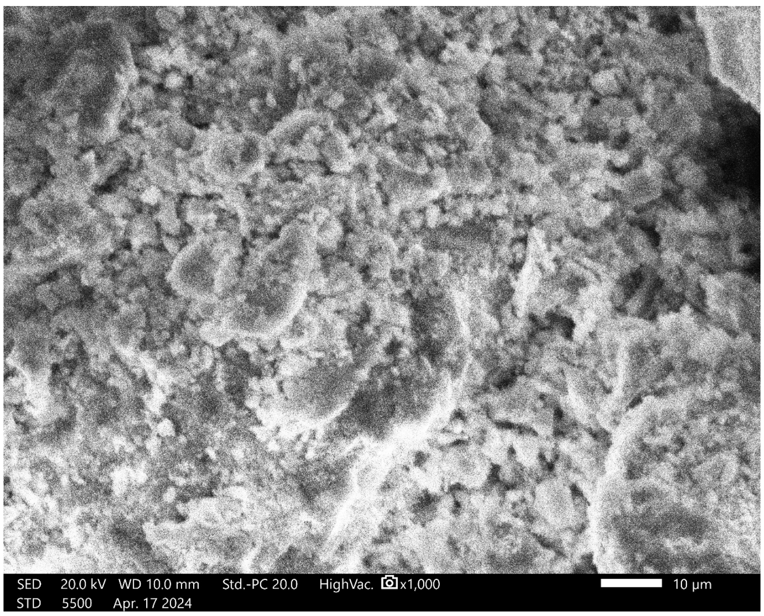

Fig. 3. Electron microscopic image of dune sands of Yazyavan.

inorganic components integrate into the ceramic matrix, improving the material's strength and thermal stability.

The form was prepared by mixing raw materials at 20 - 22 % humidity. After leaving the obtained samples in the open air for one day, they were dried at 110°C for 8 h. The samples were then burned at temperatures ranging from 900 to 1050°C, with a temperature increase of 4°C deg min^{-1}. Among the burned samples, those in orders 3, 4, 5, and 6 were found to conform to the standards, and some of their properties are presented in Table 4.

Table 3. Chemical compositions of ceramic samples (initial).

№	SiO_2	Al_2O_3	Fe_3O_4	TiO_2	CaO	MgO	Na_2O	K_2O
0	50.4	16.9	11.1	0.7	2.8	1.81	2.2	1.55
1	47.8	16.0	10.5	0.66	2.66	1.71	2.09	1.47
2	48.4	15.5	10.2	0.64	2.87	1.83	2.07	1.49
3	49.0	15.1	9.81	0.63	3.09	1.94	2.05	1.51
4	49.6	14.6	9.43	0.61	3.30	2.05	2.03	1.54
5	50.2	14.1	9.04	0.59	3.52	2.16	2.02	1.56
6	50.8	13.6	8.65	0.57	3.73	2.27	2.00	1.58
7	56.1	9.23	5.16	0.42	5.67	3.28	1.84	1.79

Table 4. Physical properties of ceramic samples.

Sample №	0	1	2	3	4	5	6	7
burned at 900°C								
density, g cm^{-3}	1.73	1.70	1.65	1.60	1.56	1.60	1.57	1.64
total linear shrinkage, %	10	10	8.4	8	6.8	6.8	6.4	5
water absorption, %	17.4	21.7	22.7	23.0	23.1	23.4	22.6	20.9
burned at 950°C								
density, g cm^{-3}	1.82	1.60	1.66	1.58	1.58	1.58	1.59	1.47
total linear shrinkage, %	9	8	9.6	8	8	7.2	6	8
water absorption, %	12.7	21.0	20.7	22.8	23.4	24.1	24.2	22.4
burned at 1000°C								
density, g cm^{-3}	1.77	1.68	1.63	1.60	1.59	1.60	1.59	1.57
total linear shrinkage, %	10	9	8	8	7,2	6.8	6.8	4
water absorption, %	11.2	17.4	21.1	22.0	22.8	23.4	22.6	23.1
burned at 1050°C								
density, g cm^{-3}	1.94	1.67	1.60	1.61	1.56	1.56	1.56	1.44
total linear shrinkage, %	12	10	9	8.4	8.4	7.6	7.2	6
water absorption, %	6	15.6	15.6	18	18.7	21	25	20.5

CONCLUSIONS

This research provides a detailed investigation into the chemical, mineralogical, and physical-chemical properties of dune sands from the Yazyavan deposit, Shursuv bentonite clay, and industrial oil sludge from the Fergana Oil Refinery, focusing on their potential as raw materials for ceramic production. The findings demonstrate that Yazyavan dune sands, particularly those from precinct 4, exhibit a high silica content, ensuring strength and durability in ceramic applications, while Shursuv bentonite clay contributes plasticity and alumina content, enhancing workability and thermal stability. The inclusion of oil sludge as a fluxing agent significantly improves the densification process and facilitates the formation of thermally stable phases such as lime (CaO) and periclase (MgO) during sintering.

The sintering process at 1050°C resulted in the elimination of hydroxyl groups and carbonates, leading to optimal ceramic compositions with density values of 1.56 - 1.61 g cm^{-3}, total linear shrinkage of 7.2 - 8.4 %, and water absorption levels of 18 - 25 %. These properties comply with standards, including GOST requirements, validating the suitability of the developed compositions for ceramic material production. Furthermore, the use of locally sourced dune sands and bentonite clay, combined with industrial waste like oil sludge, offers significant economic and environmental benefits. By reducing reliance on conventional raw materials and minimizing the environmental footprint, this approach supports sustainable and circular economy practices. Additionally, the proximity of these raw materials to production facilities lowers transportation costs and enhances economic efficiency, further strengthening the viability of this approach.

In conclusion, this research underscores the scientific and practical value of Yazyavan dune sands, Shursuv bentonite clay, and oil sludge for ceramic production. It highlights their potential to promote a sustainable, resource-efficient industrial model while contributing to the advancement of innovative ceramic materials. These findings provide a solid foundation for broader industrial adoption and future research into sustainable material utilization in Uzbekistan and beyond.

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Authors' Contributions*: A. E.: Conceptualized the research idea, developed the methodology, and provided overall supervision. A. Kh.: Conducted experimental work and performed data analysis. Z. K.: Drafted the manuscript, edited the data, and ensured compliance with scientific standards. S. M: Reviewed the content of the manuscript and performed the final revisions. All authors reviewed and approved the final version of the manuscript.*

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