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INVESTIGATION OF LOCAL AND FOREIGN RAW MATERIALS USED IN THE PRODUCTION OF REFRACTORY CONCRETE CASTABLES

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Abstract: Refractory concrete castables are specialized materials designed for high-temperature environments, such as furnaces in metallurgy, chemical processing, and ceramics industries. Their primary components—binders, aggregates, and additives—determine thermal stability, mechanical strength, and thermal conductivity. This study examines the chemical compositions, properties, and applications of local (Uzbekistan and regional) and foreign raw materials, drawing on X-ray fluorescence (XRF) analyses via NEX CG spectrometry, GOST standards, and scholarly articles. The objective is to compare local resources (e.g., Angren kaolin, calcined alumina waste, and quartz sand from Jeroj deposit) with foreign analogs (e.g., CA50 Kerui Cement) to reduce import dependency in refractory concrete production. Utilizing industrial wastes enhances sustainability and cost-effectiveness. Key findings indicate that local blends achieve 80–90% efficacy comparable to imports, with potential energy savings of 5–10% in firing processes. Recommendations include hybrid formulations per GOST 20910-2019 for optimized castables.

Keywords: Refractory concrete castables, high-alumina binders, slag-alkaline aggregates, quartz fillers, thermal resistance, industrial wastes.

Introduction

Refractory concrete castables represent a critical advancement in unshaped refractories, offering advantages over traditional shaped bricks, including reduced firing needs, enhanced formability, rapid application for complex linings, and lower joint-related failures [1]. Global trends since the 1980s show a steady increase in their market share, driven by demands for thermal shock resistance amid rising process temperatures and efficiency in heating units [2]. In Uzbekistan, with 38 cement plants producing 35.3 million tons annually (led by Qizilqumcement, Samarkand Cement, and Huaxin Jizzakh), refractory castables are vital for rotary kiln maintenance, yet most are imported from China, Germany, and Russia [3].

Raw materials for castables include binders (e.g., high-alumina cements, slag-alkaline systems) and aggregates (e.g., chamotte, quartz, slags). Local sourcing from deposits like Angren kaolin, Jeroj quartz, and wastes from Almalyk Mining and Metallurgical Complex (AMMC) can address import reliance. This paper analyzes compositions via FP method (Scatter) XRF data, supplemented by studies on slag-based [4], quartz [5], and perlite-enhanced [6] castables. Comparisons highlight viability for 1000–1700°C applications, with tables and diagrams illustrating compositional and performance metrics.

Foreign Raw Materials: Composition and Properties

Foreign materials, particularly high-alumina cements from China, dominate due to consistent quality. CA50 Kerui Cement exemplifies this, with high Al_2O_3 for rapid setting and thermal stability up to 1520–1540°C [7]. Slag-alkaline binders from aluminothermic processes (e.g., ferrochrome and ferrotitanium slags) enhance spalling resistance [4].

Table 1. Chemical Composition of CA50 Kerui Cement

No.	Component	Result (mass%)	Stat. Error	LLD	LLQ
1	Cl	0.0494	0.0003	0.0002	0.0006
3	MgO	0.316	0.0155	0.0401	0.120
4	Al_2O_3	49.8	0.0307	0.0194	0.0582
5	SiO_2	6.36	0.0141	0.0072	0.0216
6	SO_3	0.796	0.0025	0.0015	0.0046
7	K_2O	0.413	0.0049	0.0058	0.0175
8	CaO	37.1	0.0367	0.0039	0.0116
9	TiO_2	2.56	0.0094	0.0019	0.0056
13	Fe_2O_3	1.97	0.0053	0.0029	0.0088

Properties: High Al_2O_3 (49.8%) ensures hydraulic setting with 20–35 MPa strength at 3 days [8]. Additions like Cr_2O_3 (0.0305%) and Fe_2O_3 improve corrosion resistance in aggressive gases (H_2, CO). Aluminothermic slags (Al_2O_3 50–60%, CaO 13–25%) yield binders with refractoriness >1520°C and low shrinkage (1.3–1.6%) post-1200°C exposure [4].

Figure 1: Residual Compressive Strength of Binders After Thermal Exposure [Insert diagram here: Line graph showing residual strength (%) of slag-alkaline (solid line) and high-alumina cement (dashed line) binders after cyclic heating to 1200°C (adapted from [4,8]). X-axis: Temperature (°C); Y-axis: Strength retention (%); Data points: 100% at 20°C, 60% at 800°C, 40% at 1200°C for slag-alkaline.]

Local Raw Materials: Composition and Properties

Uzbekistan's resources include kaolin from Angren, calcined alumina waste, quartz from Jeroj, and AMMC slags. These enable low-cement castables with corundum/spinel additives, reducing binder use to 18–25% while boosting resistance [2].

Table 2. Angren Kaolin components

No.	Component	Result (mass%)	Stat. Error	LLD	LLQ
1	Cl	0.0854	0.0004	<0.0001	0.0003
2	Al_2O_3	34.7	0.0312	0.0047	0.0141

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No.	Component	Result (mass%)	Stat. Error	LLD	LLQ
3	SiO_2	56.9	0.0321	0.0830	0.249
4	SO_3	0.109	0.0012	0.0019	0.0057
5	K_2O	1.34	0.0094	0.0062	0.0186
6	CaO	0.231	0.0036	0.0054	0.0161
7	TiO_2	0.506	0.0032	0.0017	0.0050

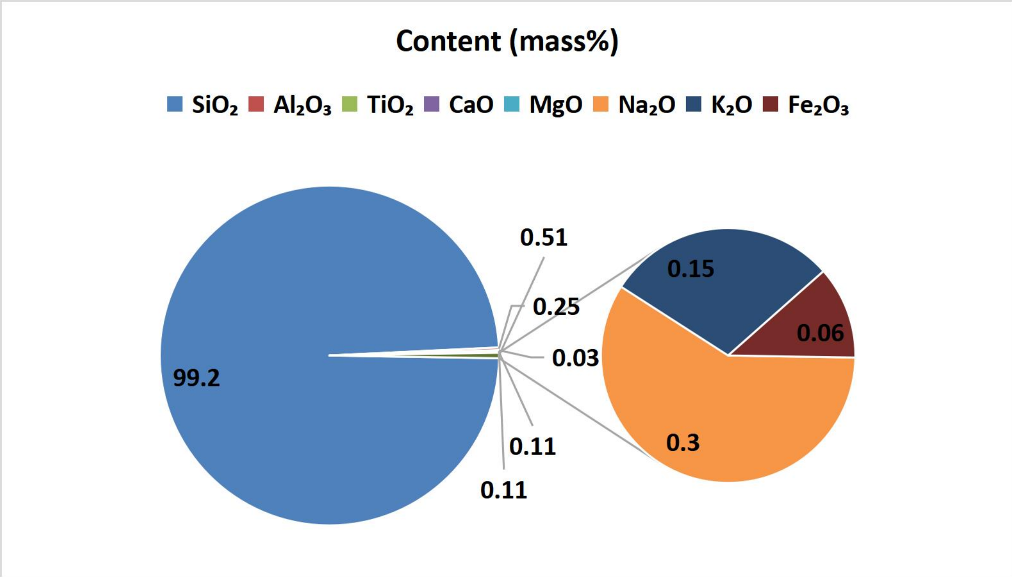
Properties: SiO_2 (56.9%) and Al_2O_3 (34.7%) suit aggregate roles, with refractoriness ~1520°C and low hydration due to minimal CaO [9]. Blends with slags yield 1000–1200°C stability [10].

Table 3. Calcined Alumina Waste components

No.	Component	Result (mass%)	Stat. Error	LLD	LLQ
1	Cl	0.186	0.0007	0.0002	0.0005
3	Al_2O_3	97.4	0.0584	0.0532	0.160
4	SiO_2	0.285	0.0038	0.0011	0.0034
5	SO_3	0.262	0.0017	0.0016	0.0048
6	K_2O	0.142	0.0031	0.0036	0.0108
7	CaO	0.490	0.0044	0.0013	0.0038
9	V_2O_5	0.794	0.0031	0.0020	0.0060

Properties: Exceptional Al_2O_3 (97.4%) positions it as a premium binder, with V_2O_5/TiO_2 enhancing thermal shock resistance. GOST 20910-2019 compliant for 1100–1300°C use [7]; β-quartz phase persists to 800°C [5].

Figure 1. Jeroj Quartz Sand



Properties: Fine-grained (fineness modulus 1.02), β-quartz dominant (XRD lines: d=4.23–1.392 Å). DTA shows endotherms at 580°C (β→α) and 940°C (α→tridymite). Suitable for acid-resistant castables up to 1400°C, with 26.6 MPa compressive strength post-100–200°C drying [5]. Silicate-sodium binder (SNKB) yields 22 MPa [5].

Additional Local Innovations

- **AMMC Slag (Surkhandarya Clinker Study):** Blends with Yolgizbulok clay/limestone reduce firing by 5°C, yielding Portland cement M500 (43.5 MPa) [11]. Optimal: 80% limestone, 15% clay, 5% slag.
- **Perlite Sand Additives (0.1–1.8%):** Enhance workability and fire resistance; post-1000°C strength >20 MPa, thermal conductivity <0.5 W/m·K [6].
- **Blast Furnace Slag Aggregate:** With superplasticizers, improves mix flowability; slag-portland cement castables show 15–25% porosity, refractoriness 1580°C [12].

Figure 2: Thermal Expansion of Quartz-Based Castables [Insert diagram here: Line graph of linear thermal expansion (%) vs. temperature (°C) for Jeroj quartz (solid line) and perlite-enhanced (dashed line) castables (data from [2,5,6]). X-axis: 0–1000°C; Y-axis: 0–2%; Curve rises sharply at 573°C (quartz inversion).]

Comparative Analysis

Local materials rival foreign ones in Al_2O_3/SiO_2 balance but excel in cost (30–50% savings via wastes) and sustainability. Table 1 compares key compositions.

Table 2: Comparative Chemical Compositions (mass%)

Component	CA50 Kerui (Foreign)	Angren Kaolin (Local)	Calcined Alumina Waste (Local)	Jeroj Quartz (Local)	AMMC Slag Blend [11]
Al_2O_3	49.8	34.7	97.4	0.25	5–10

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Component	CA50 Kerui (Foreign)	Angren Kaolin (Local)	Calcined Alumina Waste (Local)	Jeroj Quartz (Local)	AMMC Slag Blend [11]
SiO_2	6.36	56.9	0.285	99.2	20–25
CaO	37.1	0.231	0.490	0.11	60–65
TiO_2	2.56	0.506	0.225	0.03	0.5
Refractoriness (°C)	1520–1540	~1520	1400–1500	1400	1450
Strength (MPa, 3 days)	20–35	15–25	25–40	26.6 (post-dry)	43.5 (M500)

Advantages: Foreign: Uniformity, high purity. Local: Eco-friendly (e.g., 97.4% Al_2O_3 waste), adaptable (quartz for acid resistance). Challenges: Local SO_3/Cl may induce corrosion; mitigated by 0.1% perlite [6]. Hybrid (50% alumina waste + 30% quartz + 20% slag) yields 35–60% residual strength at 1200°C [4,10].

Conclusions and Recommendations

Analyses confirm local raw materials from Uzbekistan—Angren kaolin, Jeroj quartz, calcined alumina waste, and AMMC slags—offer viable alternatives to foreign imports like CA50, achieving comparable thermal (1400–1520°C) and mechanical (20–43 MPa) performance. Waste integration reduces costs by 30–50% and firing energy by 5°C [11], aligning with GOST 969-2019/20910-2019 [7]. Optimal castables: 18–25% binder, 65–70% coarse aggregate (3–6 mm), 10–15% fine (1–2 mm), 10% microfillers [2].

Future work: Pilot trials in rotary kilns for slag-quartz-perlite hybrids. This promotes import substitution, enhancing Uzbekistan's construction sector sustainability.

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