

STUDY OF THE STRUCTURE AND PHYSICAL PROPERTIES OF THE COMPOSITION OF THERMAL INSULATION MATERIALS BASED ON WASTE FROM MINING COMPLEXES

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ABSTRACT

New heat-insulating materials were prepared via the combined use of local technogenic and natural raw materials. The mixtures of natural clay, overburden of polymetallic surface mine, charcoal chips, wood crumbs, dolomite chips, and minor amounts of triethanolamine as a hardener and stearic acid emulsion as a waterproofing agent were used as starting mixtures. For the ceramic-like materials prepared by firing at 1000°C, we report their physicomaterial parameters-shrinkage ϵ , density d , abrasability a , water adsorption q , thermal conductivity k (at 50°C), and compressive strength σ_c . The synthesized ceramic masses may find their application in the fabrication of wall panels and lightweight concrete aggregates

Keywords: Technogenic Raw Materials, Clay-Filled Materials, Heat-Insulating Ceramic, Firing, Porosity.

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INTRODUCTION

As is known, local technogenic raw materials can be readily used to fabricate heat-insulating materials for use in the construction industry. To date, it has been suggested to fabricate thermal insulation materials via the incorporation of spent shea waste¹, phosphorus slag and coal gangue², fly ash³, geopolymers^{4,5}, coal fly ash^{6,7}, solid wastes⁸, local technogenic raw material⁹, bauxite tailings¹⁰, low-silicon iron ore tailing¹¹, wastes of chrysotile asbestos production¹², iron tailing¹³, and highly crystallizable industrial wastes.¹⁴ In this communication, we report on the preparation of new porous ceramic materials with good thermal insulation properties via the incorporation of wastes from the local polymetallic metallurgical plants.

EXPERIMENTAL

Material and Methods

In experiments, we used natural clay from the Bosaryk deposit (Kazakhstan) as a basis, the overburden taken from a disposal area at the Achisai polymetallic plant (Kazakhstan) as a filler, charcoal chips and wood crumbs as pore-forming agents, and dolomite chips as a strengthening agent. Optimal concentration limits for starting mixtures (wt %) are presented below:

Clay	45–55
Overburden	27–43
Charcoal chips (2–3 mm)	10–15
Wood crumbs	1–2
Dolomite chips (0.5–1.5 mm)	2–3

To the above mixtures, we also added minor amounts of triethanolamine as a hardener and stearic acid emulsion as a waterproofing agent.

General Procedure

Cubic (2×2 cm) compacts of starting mixture were dried in an oven and then fired at 1000°C . Figure-1 presents the overall view of starting and sintered samples. The moisture content of clay and overburden was 14% and 16%, respectively. The air shrinkage of clay was 5% while the fired shrinkage, 5%. Some other parameters of clay and overburden are given in Table-1.



Fig.-1: Overall View of Starting (a) and Sintered Sample (b)

Table -1: Some Characteristics of Clay Base and Overburden Filler

	Color	Structure/texture	Chalk-stone (reaction with 10% HCl)	Others
Clay	Yellow (iron oxide and hydroxide)	Fine/micro	vigorous	–
Overburden	Grey (titanium dioxide)	Coarse/micro	slow	Pyrite (FeS_2)

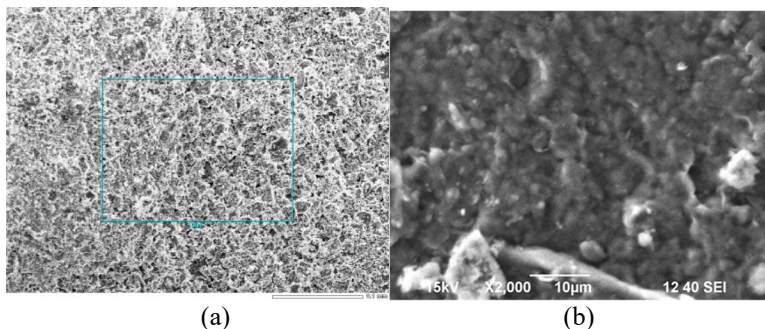
Detection Method

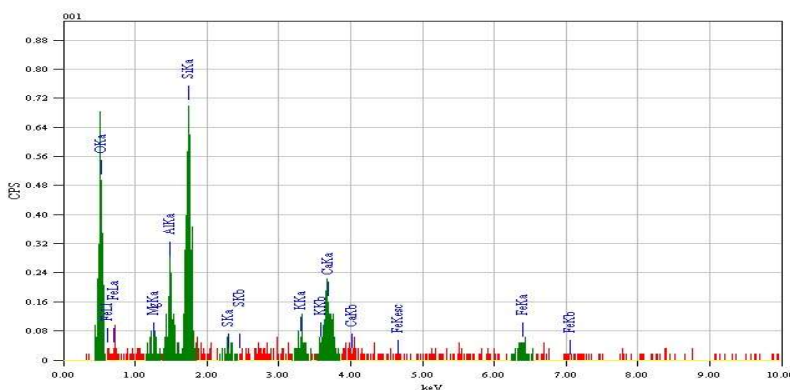
Starting materials and products were characterized by chemical analysis, XRD (DRON-3 diffractometer, $\text{Cu-K}\alpha$ radiation, PDF2 database), SEM (SESM-3200 JOEL microscope), thermogravimetry (Q-1500D derivatograph), and IR spectra.

RESULTS AND DISCUSSION

Raw Materials

Figure-2 shows the microstructure (a, b) and results of atomic absorption analysis for the overburden (c). The overburden represents a solid sintered material (Fig.-2a) comprising the oxides of magnesium, aluminum, iron, and silicon, the latter being predominant (Table-2). The high-temperature reaction between MgO and Al_2O_3 could be expected to yield spinels. It is widely known that, among these, it is only silica that is capable of forming viscous melt at high temperatures, due to which melted silica can act as a conventional solid and refractory body.





(c)

Fig.-2: Microstructure of the Overburden (a, b) and Results of its Atomic Absorption Analysis (c)

Table-2: Elemental Composition (wt %) of the Overburden as Determined by Atomic Absorption Analysis

	wt %	at. %	Bound, wt %	Cations
O	0.52	0.20	61.06	37.5
Mg	1.25	0.15	1.38	1.23
Al	1.49	0.15	6.12	6.93
Si	1.74	0.16	18.36	23.6
S	2.30	0.17	0.86	1.56
K	3.31	0.27	2.68	5,80
Ca	3.69	0,33	5,65	13,0
Fe	6.39	0,95	3,89	10,5

It is well known that the important prerequisites for the up warping of clayish raw materials during firing are the formation of (a) pyro plastic mass and (b) a sufficient amount of gaseous products.¹⁵ Our DTA results for clay have shown that the removal of adsorbed water occurs within the range 90–120°C while that of constitution water, at 460–530°C. The peak at 800°C indicates the presence of muscovite (loss of constitution water) and the decomposition of chalkstone. Our DTA results for overburden: endothermic peaks around 740°C indicate the presence of the hematite $\alpha\text{-Fe}_2\text{O}_3 \rightarrow$ maghemite $\gamma\text{-Fe}_2\text{O}_3$ phase transformation. Chemical analysis of clay (%): SiO_2 40–80, Al_2O_3 8–50, Fe_2O_3 0–5%, CaO 0.5–25, MgO 0–4, R_2O 0.3–5.

Resultant Ceramics

Figure-3 shows the SEM image of the resultant (fired) heat insulation ceramic while Table-3, its physicommechanical parameters. Synthesized materials were found to contain quartz, kaolinite, calcite, and potash feldspar.

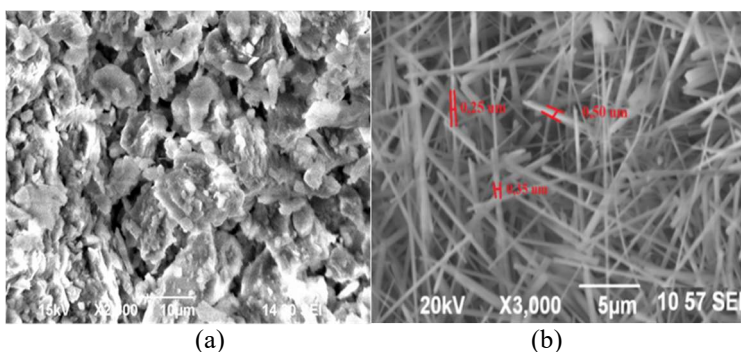


Fig. -3: SEM Images of Resultant Heat Insulation Ceramic (sample 01 in Table-3) taken at two Magnifications

Table-3: Physic Mechanical Parameters of Synthesized Materials (samples 01–04): Shrinkage ε , Density d , Abradability a , Water Adsorption q , Thermal Conductivity k (at 50°C), and Compressive Strength σ_c

Sample	ε , %	d , g/cm ³	a , g/cm ²	q , %	k , kcal/(m h K)	σ_c , MPa
01	0.25	1.54	0.1	4.5	0.1	120
02	0.23	1.55	0.12	4.4	0.12	128
03	0.31	1.49	0.2	4.3	0.15	115
04	0.30	1.50	0.12	4.35	0.14	115

Composition limits (wt %) for samples 01–04 are given below (Table 4):

Table-4				
Sample	Overburden	Clay	Wood crumbs	Dolomite Chips
01	40–46	35–45	5–10	1–2
02	47–53	25–35	10–15	2–3
03	54–60	15–25	15–20	3–4
04	61–66	10–15	20–25	4–5

Our material turned advantageous over existing heat insulation materials in such characteristics as granulometric composition, coarse-grained inclusions, plastic behavior, and drying efficiency of raw material, shrinkage, sinterability, mechanical strength, and frost resistance. As is seen in Fig.-3a, reactions of magnesium, calcium, and iron oxides with alumina (present in overburden) during thermal treatment lead to the formation of glassy spinels. The filamentous microstructure of synthesized material (armoring fibers in Fig.-3b) is optimal: deviation from the size of charcoal and dolomite chips (cf. Table-2) led to the segregation of material, water separation, the spread of starting mixture and hence to the loss of product strength. In our case, the porosity is formed due to the burn-out of charcoal chips and wood crumbs in the course of firing. At this, the newly formed glassy spinels and hydromica covered the surface of voids and overburden particles to form the homogeneous matrix shown in Fig.-3. The plasticity is ensured by the presence of clay containing hydromica, chalkstone, and quartz sand. The clay is also responsible for (a) material unwarping during thermal treatment, (b) formation of pyro plastic mass, (c) evolution of gaseous products, and (d) hydrophobicity of resultant material. Upon interaction with water, the dolomite chips form a plastic consistency that favors the place ability and thus improves the compressive strength of THE material. Upon interaction with silica, the alkali oxides of minerals formed in the course of cementation yield hydro silicates and thus improve the material strength, frost resistance, and environmental friendliness. The thermal conductivity of our material at 50°C (Table-3) is close to that of existing heat-insulating materials. Nevertheless, our process takes advantage in view of the facts that it (i) requires no preliminary treatment of clay-based raw materials and (ii) opens up a way to utilization.

CONCLUSION

The combined use of technogenic and natural raw materials affords for the preparation of heat-insulating materials with good service parameters and environment friendliness. The synthesized material can be readily recommended for use in the chemical industry, metallurgy, mining, power engineering, and construction engineering.

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