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THERMAL EXPANSION KINETICS OF GLAUCONITE-BASED ALUMINOSILICATE COMPOSITES: MASS LOSS ANALYSIS AND TEMPERATURE OPTIMIZATION

Ruzimova Shoxnoza Urunboyevna, Babaxanova Zebo Abdullayevna,

Azamatov Utkirbek Rashidovich

Tashkent Institute of Chemical Technology

shahnozaruzimova@gmail.com, 0000-0001-8567-3906

zebo.babakhanova@gmail.com, 0000-0003-4346-9450

azamatovotkirbek@gmail.com, 0000-0001-6194-8610

Annotation: This article focuses on the thermal behavior of G1 series geopolymer composites based on Changi glauconite modified with SiC and basalt. The mass loss of the samples during firing in the range 700-900 °C was studied, which is a direct indicator of the intensity of gas evolution and, consequently, swelling. The quantitative mass loss data obtained demonstrate a sharp increase in gas evolution at high temperatures and with the use of a blowing agent. It was found that firing at 700-900°C for the combined G1-2Si-2B sample results in the maximum mass loss (66.5%), indicating the optimal thermal regime for achieving minimum density.

1. Introduction

The increasing demand for energy-efficient construction materials has driven significant research into lightweight thermal insulation composites. Geopolymers, defined as amorphous aluminosilicates synthesized by the reaction of aluminosilicate precursors with alkaline activators, have emerged as a sustainable alternative to traditional ceramics and Portland cement-based materials [1]. Their unique structure allows for the incorporation of various industrial by-products and natural minerals to engineer materials with high thermal stability and low thermal conductivity.

A critical factor in the production of lightweight geopolymers is the selection of the aluminosilicate precursor. While metakaolin and fly ash are widely utilized, there is growing interest in the use of natural clay minerals such as glauconite. Glauconite, a micaceous clay mineral rich in iron and potassium, is abundant in Uzbekistan, particularly in the Changi deposit [2]. Research by Ruzimova et al. indicates that Changi glauconite possesses a chemical composition suitable for use as a precursor in the production of porous ceramic materials, offering a cost-effective utilization of local mineral resources [3]. The thermal activation of such aluminosilicates is a complex process; heating typically induces dehydroxylation between 500 °C and 800 °C, leading to structural rearrangement and the formation of reactive phases necessary for geopolymerization or sintering [4].

To achieve the low density required for thermal insulation, pore-forming agents are introduced into the geopolymer matrix. Silicon carbide (SiC) has been identified as an effective blowing agent in high-temperature applications. Lo et al. demonstrated that SiC sludge can be recycled into lightweight foamed geopolymers, where the oxidation of SiC at elevated temperatures consumes oxygen and generates gases (such as CO_2), creating a cellular structure that significantly reduces thermal conductivity [5]. The intensity of this gas evolution is

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temperature-dependent, and matching the peak gas release with the pyroplastic state of the matrix is essential for preventing structural collapse.

However, a common challenge with highly porous geopolymer foams is their reduced mechanical integrity. To address this, reinforcing fillers such as basalt fibers or powder are often incorporated. Basalt, an inorganic material derived from volcanic rock, exhibits excellent high-temperature resistance and chemical stability. Ziada et al. reported that the addition of basalt fibers to geopolymer mortars improves both compressive and flexural strength, as well as resistance to thermal shock [6]. Furthermore, recent studies on foamed geopolymers containing basalt powder have shown that the additive aids in the stabilization of the pore structure, promoting the formation of spheroidal pores which enhance insulation properties without compromising density [7].

Despite these advances, there is limited literature specifically addressing the simultaneous use of Changi glauconite, SiC, and basalt in a fired geopolymer system. The thermal behavior of such composites in the 800–1000 °C range—specifically the correlation between mass loss (gas evolution) and swelling—remains a critical area of investigation. This study aims to bridge this gap by analyzing the thermal behavior of G1 series composites to determine the optimal firing regime for maximizing expansion and minimizing density.

2. Materials and methods

2.1. Samples and thermal conditions

The work used samples of the G1 series (Glauconite:NaOH ratio 80:20) with additives of SiC and basalt.

Thermal treatment was carried out under thermal shock conditions - rapid transfer of pre-dried granules into an oven heated to a predetermined temperature: 700°C, 800°Cand 900°C. The fixed isothermal holding time was 1 hour. The highest possible heating rate is a key condition for the efficient capture of gases within the softened matrix.

2.2. Evaluation of thermal behavior

The thermal behavior of the samples was assessed by determining the mass loss. Weighing was performed before and after firing. The percentage of residual mass was calculated as the grams of residual mass divided by the initial mass.

3. Results and discussion

3.1. Change in sample mass during firing

Table 1 presents the quantitative mass loss results for key samples of the G1 series.

Table 1. Change in mass of G1 samples after firing

Sample name	Firing temperature,° C	Initial mass, g	Final mass, g	Residual mass, %	Weight loss, %
G1-0	700	9,1669	7,2530	79%	21%

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	800	9,5017	7,3342	77%	23%
	900	10,4335	8,2473	79%	21%
G1-2Si	700	9,4424	8,6515	92%	8%
	800	10,4379	7,3968	71%	29%
	900	7,2541	7,109	**98%**	**2%**
G1-2Si-2B	700	11,6304	6,8952	59%	41%
	800	7,2493	14,2374	**69%**	31%
	900	11,8558	3,9724	**33,5%**	**66,5%**

3.2. Discussion of results

1. **Effect of temperature and composition:** The sample without additives (G1-0) shows a stable mass loss of 21–23% across the entire firing range (700–900°C), which is primarily attributed to the removal of residual moisture and the structural dehydroxylation of glauconite (a process that typically occurs between 500 °C and 800 °C). In contrast, the addition of the blowing agent, Silicon Carbide (SiC), and the reinforcing filler, basalt, sharply increases the mass loss. This effect is notable for the G1-2Si sample, which jumps from 8% mass loss at 700°C to 29% at 800°C, driven by the intense, temperature-dependent oxidation of SiC to generate gases (e.g., CO2). However, a significant anomaly is observed for G1-2Si at 900°C, where mass loss drops dramatically to 2% (98% residual mass), suggesting premature matrix collapse or a temporary suppression of gas evolution at this temperature.
2. **Maximum gas evolution:** The combined sample G1-2Si-2B demonstrated the highest mass loss of **66.5% at 900°C**. This dramatic increase, supported by the quantitative data in Table 1, indicates the maximum intensity of gas evolution is achieved when both SiC and basalt are present at this specific temperature. The basalt powder's known ability to stabilize the pore structure likely complements the SiC's gas generation, ensuring the gases are captured within the softened, pyroplastic matrix. This synergistic action should lead to the maximum swelling coefficient and, consequently, the minimum bulk density for the resulting composite. The 900°C regime for G1-2Si-2B is thus provisionally identified as the optimal thermal treatment for maximizing expansion.

To quantify the expansion kinetics and validate this optimal regime, it is necessary to determine the physical parameters that directly reflect the result of thermal shock, such as bulk density and swelling coefficient.

Table 2. Planned parameters for expansion of G1 samples

Parameter	G1-0	G1-2Si	G1-2Si-2B
Bulk density, kg/m³	600	1200	200
Swelling coefficient, rel. units	1.8	0.9	5.0

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Appearance (swelling assessment)	Good	Compaction	Excellent

4. Conclusion

Thermal shock in the range of 700-900°C effectively initiates swelling of glauconite-based geopolymer composites. The observed maximum mass loss (66.5%) for G1-2Si-2B and the anomalous behavior of G1-2Si confirm the need for further optimization of the temperature regime. Density measurements, swelling coefficient, and microstructural analysis will allow us to precisely determine the optimal process window for producing ultra-lightweight aggregate.

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