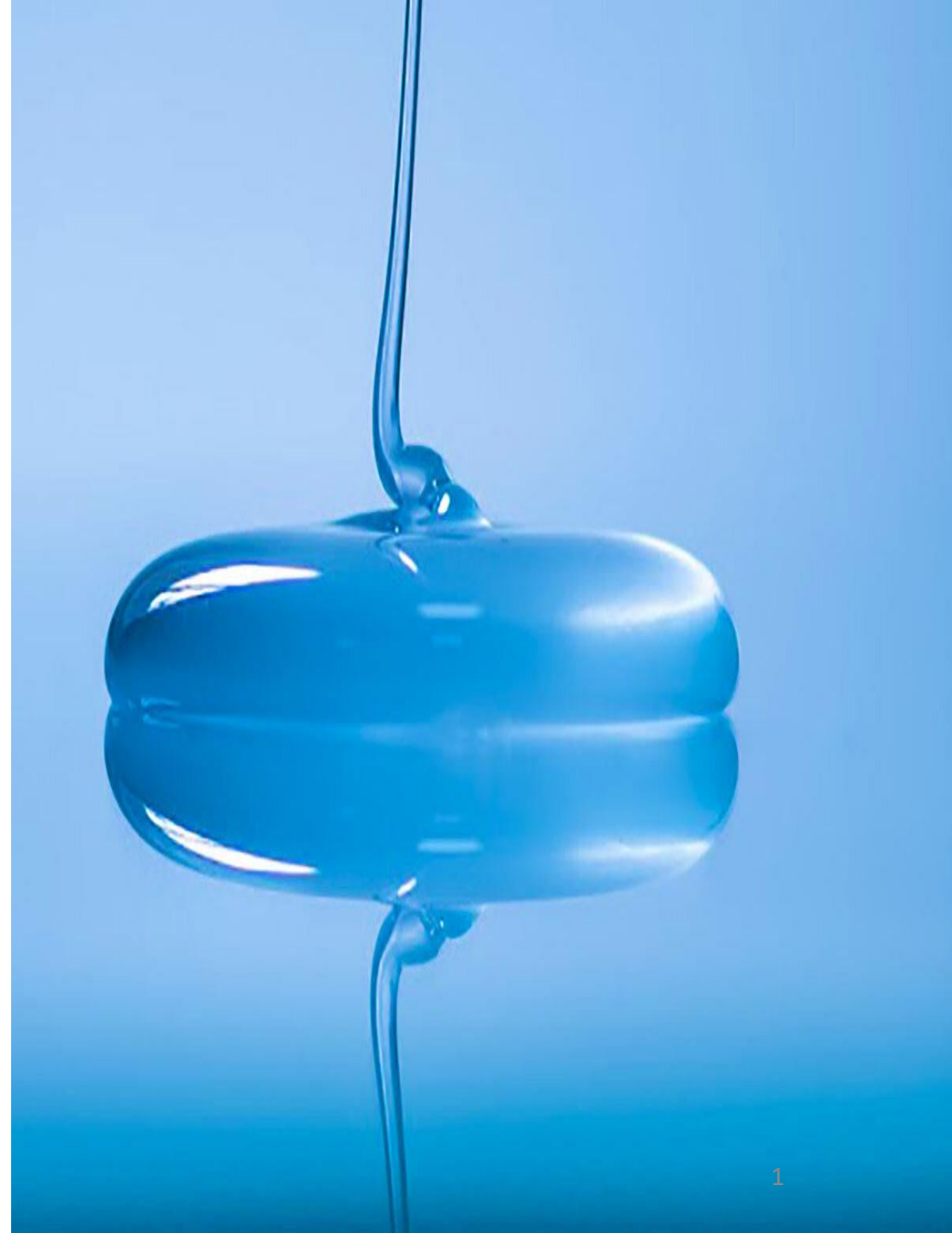


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Rheology of Building Materials

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**RHEOLOGICAL PROPERTIES OF
MIXTURES BASED ON ALKALI METAL
SILICATE MIXTURES**

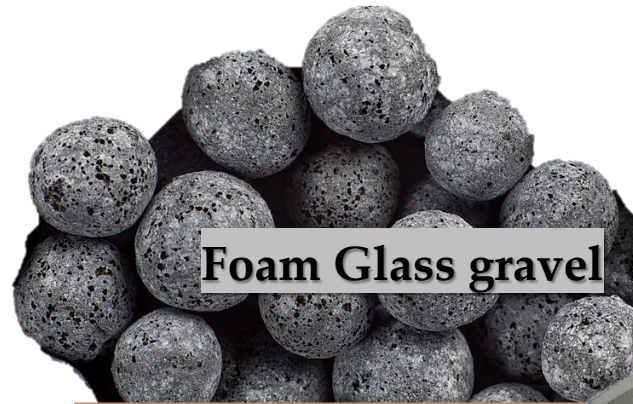
The speaker: Malova Elina Aleksandrovna, post graduate student at the NRU MSUCE, leading engineer of the NIISF RAACS, Moscow, Russia



Research motivation



Reduce energy consumption



Non-flammable, environmentally friendly thermal insulation materials based on foamed compositions



Foamed materials based on waterglass

Study Purpose & Scope

Goal

Control rheological properties that determine structural, mechanical and technological behaviour of mixtures. Determination of the influence of viscosity on the foaming coefficient of a material.

Materials

Sodium silicate solutions with added powdered sodium metasilicate (Na_2SiO_3) at varied concentrations.

Method

Measure density and kinematic viscosity; microwave treatment to produce porous cellular liquid glass.

Key Experimental Compositions

Control

Initial sodium silicate solution, no added Na_2SiO_3 .

15% Na_2SiO_3

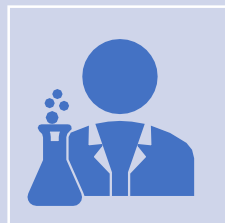
Solution with 15% powdered sodium metasilicate added.

30% Na_2SiO_3

Solution with 30% powdered sodium metasilicate added.



Determining the kinematic viscosity of the material is necessary to analyse the behaviour of the mixture at the stage of pouring into a mold. The change in viscosity of liquid glass with increasing concentration was determined, thereby obtaining the values of kinematic viscosity.



The dependence of the density of a sodium silicate solution on its concentration was determined. The test was conducted at a controlled temperature of 20°C . The hydrometer reading was recorded when equilibrium was reached within the vessel, without touching the vessel walls, along the upper meniscus of the solution.

Measurement Methods

The used solutions of liquid glass were poured into the vessel until a convex meniscus appeared above the edge of the viscometer. Then the nozzle was opened and the time from the beginning of the appearance of the test mixture to the first interruption of the mixture was recorded. The test was performed three times, after which the average value in seconds was calculated.

Kinematic viscosity measured with capillary viscometer (100 ml vessel); flow time averaged over three runs ($\pm 3\%$ permissible deviation).

Viscosity formula: $V = T \cdot K$

V – viscosity, mm^2/s ;

K – viscometer constant (here 1.38), mm^2/s^2 ;

T – expiration time of the studied solutions, s.

Microwave Foaming Protocol

An alternative method of heat treatment is the foaming of a liquid-glass mass not by introducing surfactants, but by forming a porous structure during exposure to microwave radiation on water molecules in a sodium silicate solution.

Mixtures subjected to microwave treatment to cure and form porous structure. All three samples processed at fixed power and time: 800 W for 12 minutes.

Foaming coefficient = volume after treatment / initial mould volume.

The effect of the viscosity of the system on the foaming coefficient of the obtained material was determined.



Samples of the material



Microwave foaming equipment

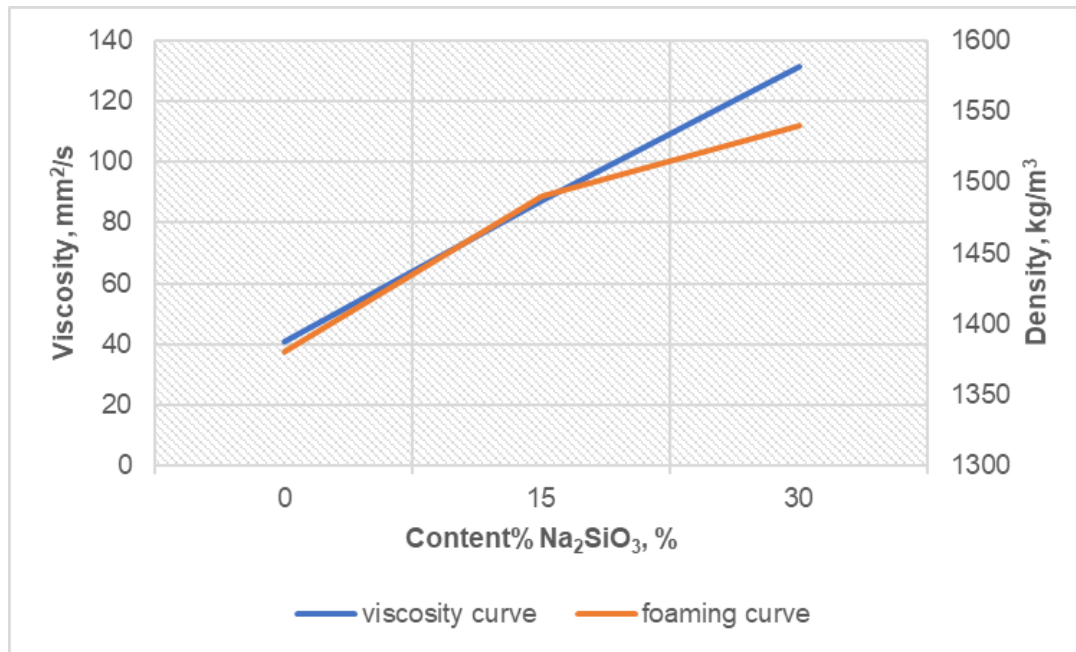
Results – Density, Viscosity, Foaming

- A summary table of the results of density, kinematic viscosity measurements and the obtained foaming coefficients are presented.

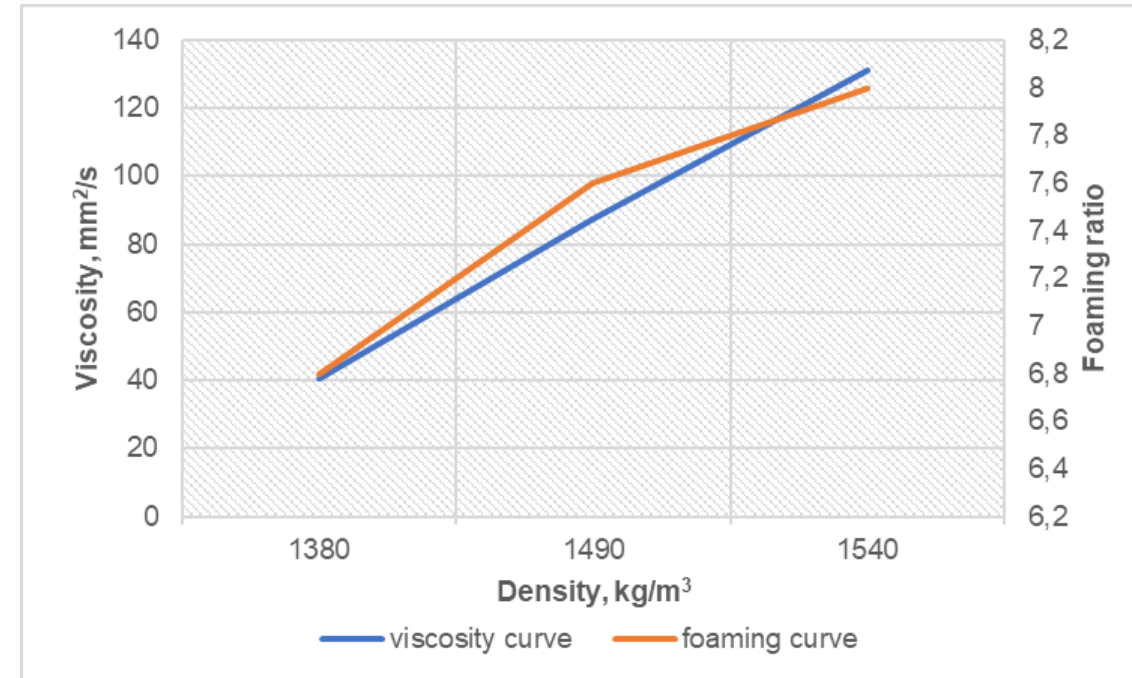
Content% Na ₂ SiO ₃	Time of liquid flow through the viscometer, s	Average time of liquid flow through the viscometer, s	Viscosity, mm ² /s	Density of compounds, kg/m ³	Foaming ratio
0	30.57	29.5	40.71	1380	6.8
	29.25				
	28.85				
15	63.5	63.4	87.492	1490	7.6
	64.1				
	62.7				
30	93.7	95.1	131.238	1540	8
	97.5				
	94.2				

Results – Density, Viscosity, Foaming

The obtained dependences of viscosity and density on the concentration of sodium metasilicate and the dependence of viscosity and foaming coefficient on density are shown.



Dependence of viscosity and density on the concentration of Na₂SiO₃



Dependence of viscosity and foaming coefficient on the density of the mixture

Observed Dependencies

Density vs Concentration

Density of compound increases as Na_2SiO_3 concentration rises (1380 → 1540 kg/m^3).

Viscosity vs Concentration

Viscosity grows with added powdered Na_2SiO_3 ; minimum viscosity at no addition.

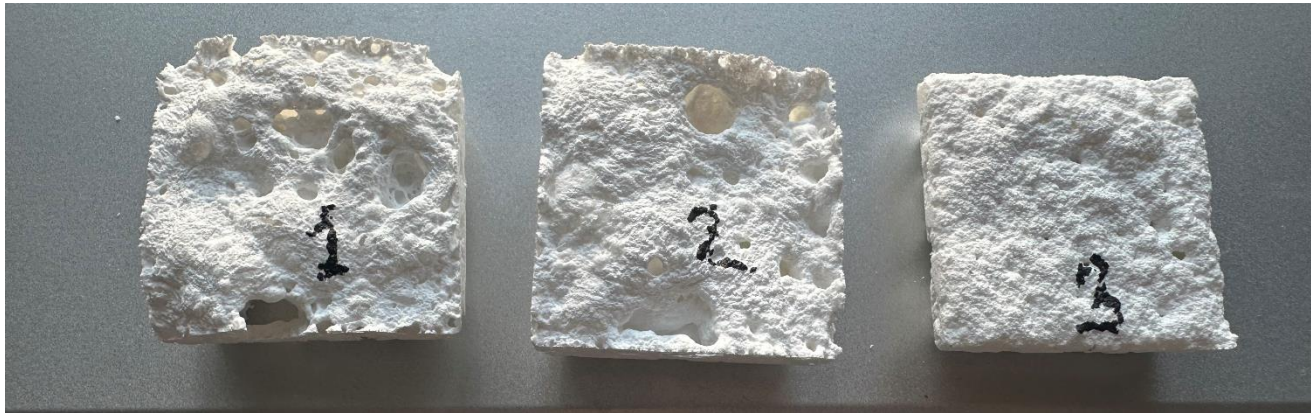
Foaming Coefficient


Foaming ratio increases with viscosity, but uniform porous structure is optimal at $\sim 87.5 \text{ mm}^2/\text{s}$.

The viscosity of the sodium silicate solution depends on the concentration and density. As the concentration of sodium metasilicate in the solution increases, the density of the mixture also increases. A comparison of the viscosity with a constant composition but different ratios shows that the sodium silicate solution has a minimum viscosity without additional introduction of anhydrous sodium metasilicate. The viscosity increases as the concentration increases by adding powdered, finely dispersed sodium metasilicate. It is shown that at a concentration of Na_2SiO_3 in the amount of 15%, the density and viscosity correspond to 1490 kg/m^3 and $87.5 \text{ mm}^2/\text{s}$.

Optimal Conditions & Microstructure

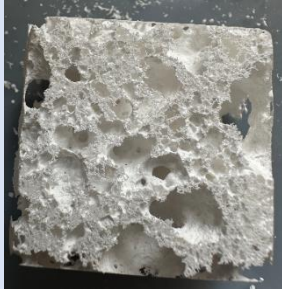






At viscosity $\approx 87.5 \text{ mm}^2/\text{s}$ (15% Na_2SiO_3) the material achieved the optimal foaming coefficient while preserving a uniform porous structure. Higher viscosity produced higher foaming but caused large pores and uneven structure.



 Balance viscosity to retain pore uniformity while achieving required expansion.

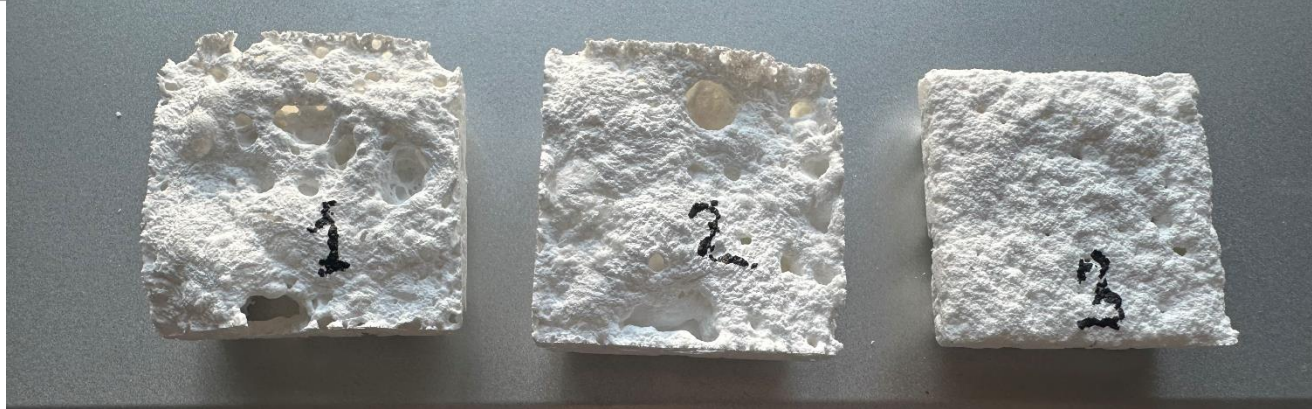
The study demonstrated that rheology plays a significant role, as by using the structural and mechanical properties of liquid raw materials as control parameters and applying objective methods and tools for operational monitoring, we can regulate the quality of both the raw mix and the resulting material. The study also calculated kinematic viscosity, which is necessary for analyzing the mechanism of pouring the mixture into the production mold.

Compositions of materials based on foamed liquid glass, filler and structure-forming additive

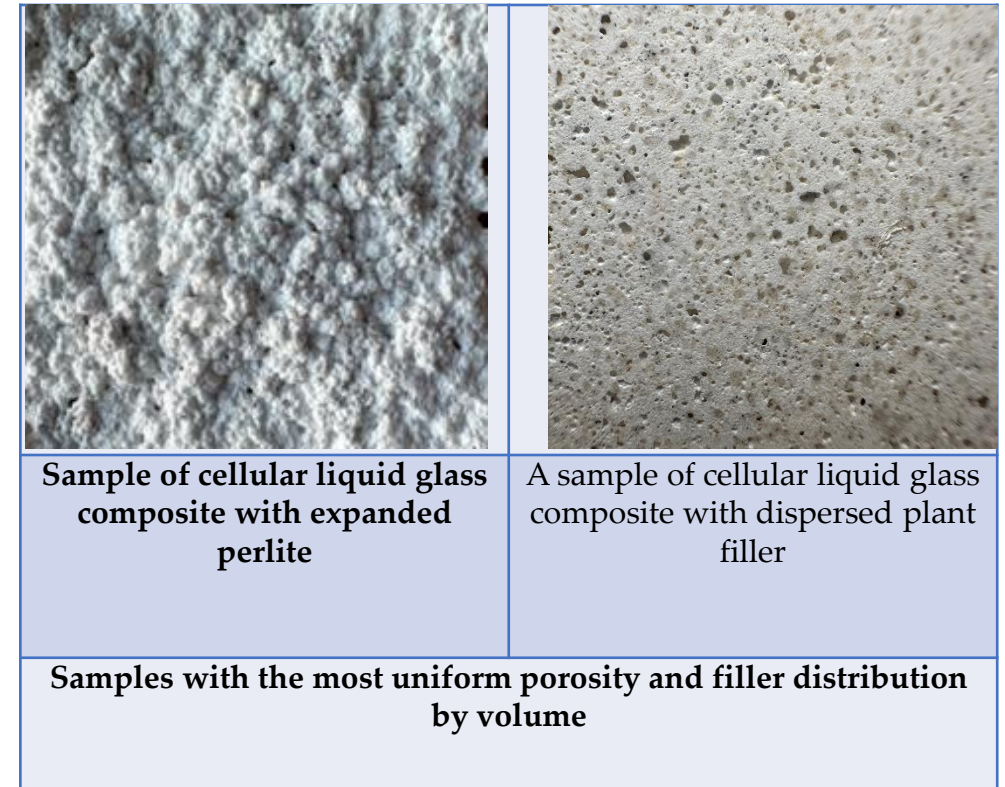
No	Compound	Technological parameters	Description	Appearance
1	Liquid sodium glass 65-80% Water 20-35%	Power: 850W Stirring time: 3 min Heat treatment time: 4 min	A macroporous structure with uneven porosity distribution, the presence of depressions and through craters. At the maximum liquid glass content in the range, denser structure was observed, but the presence of craters was retained.	  min. LG content max. LG content
2	Liquid sodium glass 30-40% Water 10-20 % Surfactant 40-60%	Power: 850W Stirring time: 3 min Heat treatment time: 5 min	The absence of depressions and craters, the structure is more uniform and predominantly microporous. With the maximum content of liquid glass and the minimum surfactant, the structure became denser.	
3	Liquid sodium glass 20-30% Water 5-15% Surfactant 25-35% Expanded perlite 20-50%	Power: 850W Stirring time: 3 min Heat treatment time: 5 min	A coherent microporous structure with the highest surfactant content. The lowest content contributed to the formation of uneven porosity.	  20% perlite 50% perlite
4	Liquid sodium glass 20-30% Water 5-15% Surfactant 25-35% Dispersed plant filler 20-50%	Power: 850W Stirring time: 3 min Heat treatment time: 4 min	A coherent microporous structure with the highest surfactant content. The lowest content contributed to the formation of uneven porosity.	  20% plant filler 50% plant filler

Compositions of materials based on foamed liquid glass, filler and structure-forming additive

Dependence of the density and structure of the obtained material samples on the power of heat treatment in microwave fields



№	Compound	Technological parameters	Sample density
1	Sodium silicate 30-40% Water 10% Surfactant 40-60%	Power: 850 W Processing time: 5 min	250-280 kg/m ³
2	Sodium silicate 30-40% Water 10% Surfactant 40-60%	Power: 1200 W Processing time: 5 min	290-310 kg/m ³
3	Sodium silicate 30-40% Water 10% Surfactant 40-60%	Power: 950 W Processing time: 5 min	270-290 kg/m ³



Research on increasing the water resistance of a matrix based on foamed liquid glass.

№	Compound	%, mas.	θ
1	Sodium liquid glass $\text{Na}_2\text{O} \cdot 2,7\text{SiO}_2$	80- 85	110°
	Organosilicon water repellent Sodium ethyl silicate $(\text{C}_2\text{H}_5\text{Si}(\text{OH})_2\text{ONa})$	15- 20	
2	Sodium liquid glass $\text{Na}_2\text{O} \cdot 2,7\text{SiO}_2$	82- 85	0
	Slaked lime $\text{Ca}(\text{OH})_2$	15- 18	
3	Sodium liquid glass $\text{Na}_2\text{O} \cdot 2,7\text{SiO}_2$	85- 95	120°
	Portland cement the main reactive phase - $3\text{CaO} \cdot \text{SiO}_2 (\text{C3S})$	5-15	

1. A composition for producing a foamed glass composite containing sodium liquid glass $\text{Na}_2\text{O} \cdot 2,7\text{SiO}_2$ with a silicate modulus of 2.7, characterized in that high-alite Portland cement was used as a hardener, with the following ratio of components, wt.%: sodium liquid glass - 85-95; high-alite Portland cement - 5-15.

2. A method for producing a foamed glass composite, including heat treatment of a composition containing sodium liquid glass $\text{Na}_2\text{O} \cdot 2,7\text{SiO}_2$ with a silicate modulus of 2.7 in an amount of 85-95 wt.% and high-alite Portland cement - 5-15 wt.%, and for heat treatment, microwave treatment with a power of 800 W is used for 4 minutes.



The surface hydrophobicity was determined by the contact angle.(θ)

Conclusions

- Rheology is a key control parameter for quality of raw mixture and final cellular liquid glass materials.
- Density and kinematic viscosity depend on Na_2SiO_3 concentration; both rise with added powdered metasilicate.
- Optimal porous structure and foaming coefficient observed at viscosity $\approx 87.5 \text{ mm}^2/\text{s}$ (15% Na_2SiO_3) under microwave processing (800 W, 12 min).
- The rheotechnological properties of mixtures are being studied, including the dynamic viscosity index, which is important for non-Newtonian liquids, to produce highly porous thermal insulation materials on an inorganic basis using a hardener, Portland cement, and finely ground waste from the production of this material.

Implications & Next Steps

Quality Control

Implement rheological monitoring (density, kinematic/dynamic viscosity) during production to achieve the required foaming ratio.

Process Optimization

Refinement of microwave processing parameters and composition to achieve uniform porosity and specified thermal insulation properties.

Further Research

Study dynamic viscosity for non-Newtonian behavior and effects of hardeners, fillers and cementitious additives on final performance.

Thank you for attention!



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