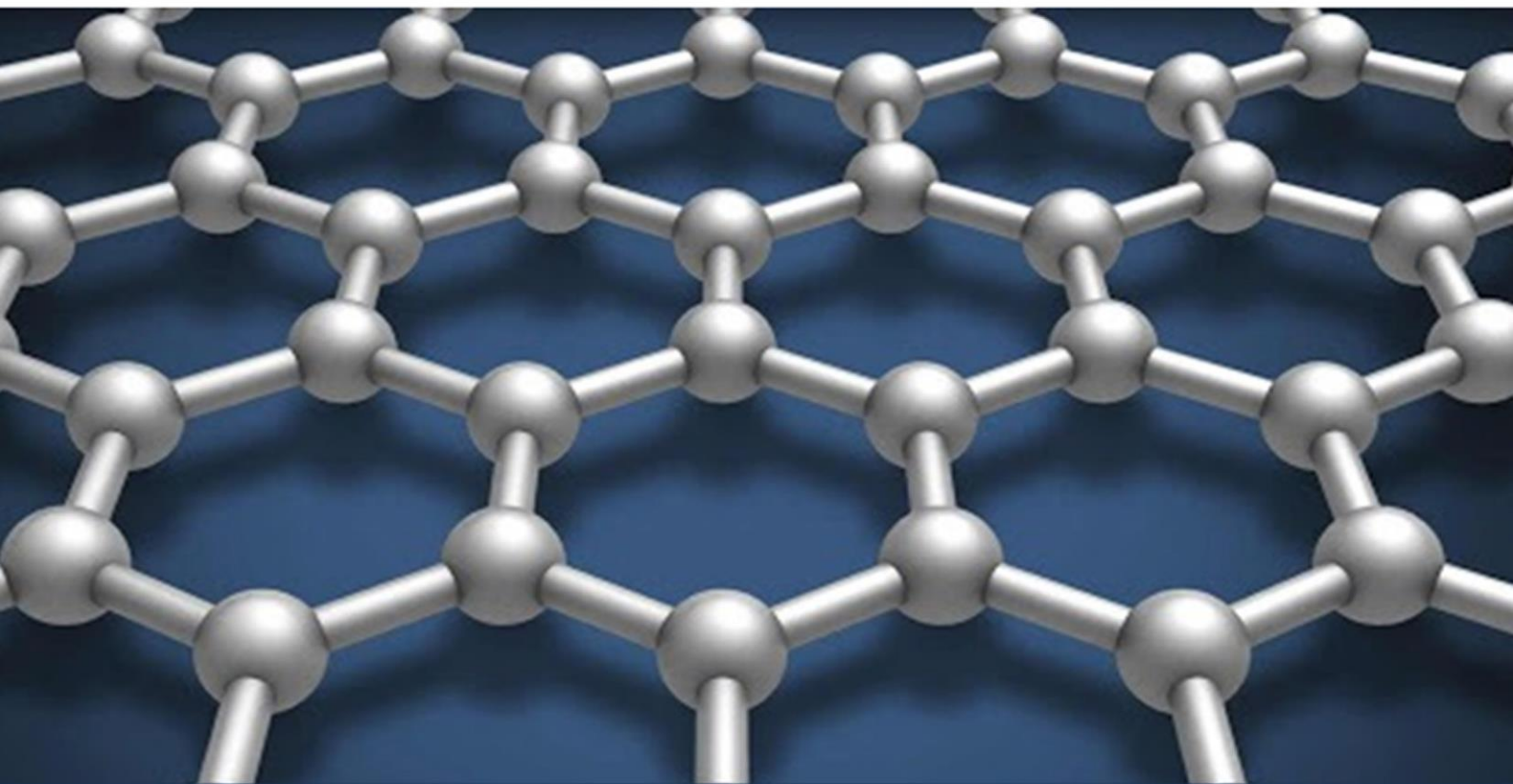


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RHEOLOGICAL AND MECHANICAL PROPERTIES OF MICROSILICA COMPOSITE GROUTING MATERIALS FOR SOIL WALL STABILIZATION IN OIL WELL CASING

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Abstract. This work presents the results of producing cement-microsilica composite plugging materials using microsilica. The influence of microsilica on the rheological properties and strength characteristics of the resulting cement composition was investigated. The study showed a significant improvement in the rheological and mechanical properties of compositions based on Portland cement and microsilica, as well as their technological characteristics.

Keywords: cement, industrial waste, microsilica, cement-microsilica composition, bulk density, normal consistency, setting time, compressive strength, structure formation.

Introduction. In the oil and gas industry of the republic, one of the current directions is the development of new cementing materials and their application in cementing casing strings – securing the soil walls of oil and gas wells under various geological conditions – as well as the production and use of composite cementing materials with the incorporation of finely dispersed industrial waste as an active mineral additive, along with various chemical additives that enhance the reactivity of cement slurry mixtures during the formation of composite coatings on the soil walls of wells [1].

The production of high-performance composite cementing materials based on cement and finely dispersed industrial waste allows for the formation of a durable stone-like coating on the surface of the wellbore walls during the hardening of the slurry mixtures. One of such materials can be cement-microsilica composite materials obtained using finely dispersed silica fillers [3-5].

At the same time, the main requirement for a cementing slurry is to ensure the tightness of the annular space and to prevent inter-column manifestations. Therefore, cementing slurries must meet the required rheological and structural-mechanical parameters depending on the hydrogeological conditions of construction.

Improving the rheological and physico-mechanical properties, as well as reducing the cost of cementing materials, can be achieved by using composite materials obtained with finely dispersed silica waste as active mineral additives in the production of cement-microsilica composite cementing materials.

Objects and methods of research. To meet the required rheological and structural-mechanical characteristics, and in accordance with the research objectives, materials for experimental studies on the selection of raw components for the cement-microsilica composition were chosen based on their availability and economic parameters, which ultimately affect the rheological and physico-

mechanical properties, as well as the cost of the mixtures and products based on them.

In the experiments, Portland cement M400 DO from the Jizzakh Cement Plant, produced by the dry method and meeting the requirements of GOST 10174-90, was used as the hydraulic binder. The quality of Portland cement was determined in accordance with State Standard 5382-2019.

As a microfiller, finely dispersed silica waste from "Uzmedkombinat" – microsilica – was used. Condensed microsilica is formed during the smelting of ferrosilicon and its alloys at "Uzmetkombinat" (Bekabad Metallurgical Plant). It contains a large amount of amorphous silica in the form of very fine spherical particles, which are formed from part of the silicon monoxide after oxidation and condensation. In the technological process, part of the silicon monoxide (SiO₂) forms an extremely fine product that appears as an ultrafine powder. Its particles are amorphous silica with a specific surface area of approximately 18–20 m²/g. The average granule size is about 0.1 μm, which is a hundred times smaller than the average cement grain size [6–8].

Cement-microsilica compositions were prepared by mixing the components in various proportions in a laboratory mixer for 15 minutes until a homogeneous composition was obtained.

The specific surface area of the composite binders was determined using a PSH-4 device. Prepared beam specimens measuring 40×40×160 mm based on the cement-microsilica composition were tested for flexural and compressive strength using a hydraulic press PGM-500MG4A. The rheological characteristics of the developed slurry mixtures were also studied.

The setting times of the slurries, normal consistency, and density of products based on cement-microsilica compositions were determined in accordance with GOST 10174-90.

Lime was added to the cement-microsilica composition to improve the plastic properties of the

slurries, reduce shrinkage deformations, serve as a water-retaining additive, and increase the working life of the slurry.

Results and discussion. During the development of high-performance cement-microsilica compositions for the production of cementing materials with specific structural-

mechanical characteristics, preliminary control studies of the chemical composition of the components of the cement-microsilica composition were carried out.

Table 1 presents the chemical composition of the raw materials used for the production of the cement-microsilica composition.

Table 1

Chemical composition of raw materials for the production of cement–microsilica composition

№	Material	Oxide Content, wt.%								
		SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	R ₂ O	PPP	Total
1	Portland Cement	23,96	4,70	0,79	66,76	2,86	0,57	0,30	-	100,0
2	Microsilica	93,80	0,70	0,90	1,20	1,00	0,20	0,59	0,60	97,96

The results obtained are close to those reported by the authors [5, 7].

Next, the effect of microsilica addition on the rheological and physico-mechanical properties of the composite slurry was studied. The composition included hydraulic binders, microsilica as a fine filler, and lime.

The study results (Table 2) showed that with an increase in microsilica content up to 10% in the composite binder mixture, the specific surface area reaches up to 5600 cm²/g.

Investigation of the rheological properties of the developed cement–microsilica compositions showed that the water demand of the slurry increases due to the presence of highly dispersed microsilica, which requires more water to wet its particles than the original Portland cement. The average particle size of microsilica is 0.35–0.65 μm, which is significantly smaller than the average cement particle size of 6.0 μm. With the addition of microsilica to the composite mixture, the water demand of cement–microsilica compositions increases from 25.0% to 37.0%. The results of the study are presented in Table 2.

It is known that the physico-mechanical properties of cements depend on the normal consistency, fineness of grinding, and various additives. In this regard, studies were conducted to examine the effect of microsilica content on the setting times of cement–microsilica compositions intended for the production of cellular heat-insulating materials.

To determine the setting times of the developed composite binders, the Vicat apparatus was used. The study of setting times showed that with an increase in microsilica content, both the initial and final setting times of the slurry increase. The results of the changes in specific surface area of the composite binder mixtures and the rheological properties of cement–microsilica composite slurries are presented in Table 2.

It was established that with an increase in the amount of microsilica in the composition, the water demand of the composite binders rises, the hydration process of the binder slows down, and, as a result, the setting time of the composite slurry is extended.

Table 2

Rheological Properties of Cement–Microsilica Compositions

№	Composition, wt.%			Specific Surface, cm ² /g	Normal Consistency, %	Setting time, min	
	Portland cement	Microsilica	Lime			Start	End
	1	100,0	-		2950	0,26	120
2	92,5	2,5	5,0	3650	0,28	120	205
3	90,0	5,0		4450	0,31	135	210
4	87,5	7,5		4950	0,36	150	225
5	85,0	10,0		5450	0,37	165	235
6	82,5	12,5		5600	0,37	170	230

To study the influence of microsilica on the strength characteristics of the developed composite binders, standard samples measuring 4×4×16 cm were prepared from a normal-consistency paste.

The conducted studies showed that the presence of finely dispersed microsilica in the cement composition improves the structure formation process by filling the voids in the hardened cement stone structure. As a result, the self-released water in the hydration process of the cement clinker monominerals is restored, the adhesion of the cement matrix to the fine filler increases, and a dense structure is formed.

The studies also demonstrated that the pozzolanic reactions of finely dispersed microsilica, as a chemical factor, further enhance the strength and durability of the products [5–7].

The results of changes in the strength characteristics of cement–microsilica compositions are shown in Table 3.

Table 3.

Effect of Microsilica Content on the Strength of Cement–Microsilica Compositions

№	Composition, wt.%		Compressive strength, MPa		
	Portland cement	Micro-silica	3 days	7 days	28 days
1	100,0	-	18,7	26,7	39,8
2	97,5	2,5	19,8	28,4	42,0
3	95,0	5,0	23,6	32,0	47,5
4	92,5	7,5	27,3	36,7	49,3
5	90,0	10,0	30,3	38,7	50,2
6	87,5	12,5	31,2	39,5	50,4

Study of the hardening process of composite binders showed that during the first 7 days of hardening, the influence of micro-silica on the strength properties is noticeable. The interaction of micro-silica particles with the hydration products of cement monominerals begins at the early stages of hardening of the slurry based on composite binders and continues until the 28th day.

Based on the obtained research results, highly effective compositions of cement–micro-silica composites have been developed for the production of construction materials and products, applied in the construction industry.

Conclusion. Based on the conducted research, it was established that the introduction of micro-silica into the cement mixture and the production of

composite cementing materials has a positive effect on the rheological properties of both the composite slurry and the bulk density of the stone wall of soil walls in wells made from these materials.

During the formation of hydration compounds of cement monominerals, the fine particles of micro-silica fill the space between the coarse particles of the cement hydration products, which sharply reduces water separation from the composite slurry.

The use of cement–micro-silica composites in the production of cementing materials with good structural and mechanical properties, with the addition of micro-silica, contributes to obtaining a stone wall with a bulk density of 400–800 kg/m³, which exhibits high corrosion resistance.

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