

**OPTIMAL COMPOSITIONS OF LIGHTWEIGHT, THERMALLY INSULATING
CONCRETES WITH VERMICULITE BASED ON LOW-WATER-DEMANDING
CEMENTS.**

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ANNOTATION: Expanded vermiculite is a natural layered silicate, and due to its high porosity, low density, and low thermal conductivity, it is a promising filler for creating lightweight and energy-efficient materials in construction. The mineralogical properties of vermiculite, its thermo-mechanical behavior, its role in mixtures, the effectiveness of its thermal insulation properties, as well as its contribution to the energy efficiency of buildings, are studied.

ENTRANCE

The development of new, environmentally friendly and energy-efficient materials for the construction industry is one of the global demands. Vermiculite, a natural mineral, when expanded, becomes a porous, very lightweight, and poorly conductive filler. This filler is used in various composite materials, including concrete, slabs, and gypsum-based composites. In recent years, the introduction of vermiculite into construction has been proven to significantly reduce energy loss, increase fire resistance, and reduce the weight of structures. This article will highlight this scientific basis.

In the modern global construction industry, the need for energy efficiency, environmental sustainability, and fire resistance is increasing. Especially in regions with high heating and cooling costs, thermal insulation of buildings and structures and construction materials with lightweight but strong structures are becoming a priority. In such conditions, lightweight concrete is distinguished by its energy efficiency, strength, and fire resistance compared to traditional heavy concrete.

Lightweight concretes — is attracting attention as one of the sustainable and effective solutions in the construction industry. In particular, lightweight concretes based on natural expanded mineral aggregates (e.g. vermiculite, perlite) are characterized by thermal insulation, fire resistance, and light structural load. Vermiculite is a silicate mineral characterized by low density, high porosity, and heat capacity, which radically changes the structural and thermal properties of concrete when used as a filler aggregate in a cement matrix.

Previous research: have shown positive results in terms of thermal insulation, fire resistance and mechanical properties of vermiculite and perlite lightweight concrete. In addition, there is practical experience in introducing vermiculite-based technologies in the production of lightweight concrete blocks and panels;

Until now — Many problems, such as the optimal composition, strength properties, water absorption, and fire resistance of vermiculite lightweight concrete based on local raw materials, have not been fully resolved. Therefore, a comprehensive study of the physical-mechanical, heat-resistant, environmental, and fire-resistant properties of vermiculite-based concretes, as



well as the development of recommendations for their implementation on an industrial scale, is an important scientific and practical task.

Purpose — to create optimal compositions of lightweight concrete based on vermiculite, to determine their physical-mechanical, thermal and fire resistance properties on an experimental basis, to determine the optimal composition and to develop practical recommendations for production.

The main objectives of the study are:

1. Determination of density, volume, and other structural properties of lightweight concrete when vermiculite is added as a filler;
2. Determination of compressive strength of concrete;
3. Determination of thermal conductivity properties;
4. Fire - testing the properties of concrete in high temperature conditions;
5. Microstructure (SEM, XRD) analysis - determining the state of bonding between the filler and the binder, voids and porosity;
6. Based on the determined results, selecting the optimal composition and developing recommendations for use in production conditions.

This study covers a number of scientifically novel areas: large-scale measurements of vermiculite-modified lightweight concretes, comparisons with international literature, and opportunities for practical implementation in local conditions.

Finally, the research results can not only be published in scientific journals, but also have practical applications in the construction industry - in the construction of thermal insulation wall panels, fire-resistant blocks, energy-efficient houses, and insulation of industrial facilities.

Based on the results of the research, a patent for the invention "Composition for obtaining lightweight concrete" was obtained.

The composition for obtaining lightweight concrete includes Portland cement, expanded vermiculite, plasticizing additives, and water, differing in that it contains a superplasticizer based on sodium polymethylene naphthalate as a plasticizing additive, additionally containing crushed granulated blast furnace slag with a fraction of 5-20 mm, dihydrate gypsum with a fraction of 5-20 mm, coreless silicon carbide fiber and mineral-organic porous filler in the following ratio of components, wt.%:

portland cement	12,0
crushed granulated blast furnace slag 5-20 mm fraction	30,0
dihydrate gypsum stone 5-20 mm fraction	10,0
silicon carbide fiber	2,0



mineral-organic porous filler	36,4
Polycarboxylate superplasticizer	0,6
water	9,0
where the mineral-organic porous filler contains the following components, wt.%:	
expanded vermiculite 5-10 mm fraction	50,0
microspheres: aluminosilicate ASPM-500	50,0

The essence of the invention: The composition for obtaining lightweight concrete included Portland cement, expanded vermiculite, plasticizing additive and water. The composition included a polycarboxylate-based superplasticizer as a plasticizer, and additionally contained crushed granulated blast furnace slag with a fraction of 5-20 mm, dihydrate gypsum with a fraction of 5-20 mm, carbide silicon fiber and mineral-organic porous filler in the following ratio of components, wt.%:

portland cement	12,0
crushed granulated blast furnace slag 5-20 mm fraction	30,0
dihydrate gypsum stone 5-20 mm fraction	10,0
silicon carbide fiber	2,0
mineral-organic porous filler	36,4
Polycarboxylate superplasticizer	0,6
water	9,0
where the mineral-organic porous filler contains the following components, wt.%:	
expanded vermiculite 5-10 mm fraction	50,0
microspheres: aluminosilicate ASPM-500	50,0

The invention relates to the production of building materials and articles, in particular, thermally insulating lightweight concrete. As a filler in D1 [D1- Burlakov G.S. Technology of lightweight concrete products: A textbook for students of special directions of universities. "Production of building products and structures". - M.: Visshaya. shk., 1986. - 296 p.] lightweight concretes based on cement binder, large and small fillers are known. The disadvantages of D1 are the insufficient thermal conductivity, density and strength of the cement product.



Expanded clay, thermolite, agloporite, slag pumice, granular slag, expanded perlite, etc. are used.

D2 is known from [D2-Buzhevich G.A. «Lightweight concretes based on porous fillers», Moscow, [Construction Literature Publishing House, 1970] composition for the production of wood-concrete materials. The composition of the raw materials is presented in the following proportions of the components, in % by weight:

Mineral binder (portland cement)	30
Wood filler	40
Mineral filler (expanded vermiculite)	10
Liquid bottle	0,6
Water	the rest

In D2, any type of cement is used as a mineral binder; crushed lime is added to preserve it, which also serves as an antiseptic for wood filler.

Despite all its advantages, D2 has one significant drawback, namely its high cost due to the significant amount of mineral binder - cement in its composition. In addition, another disadvantage of D2 is the use of organic - wood filler, which also affects the economic component, namely the increase in the cost of concrete during its production. The composition for the production of lightweight concrete from D3 [D3 - RU 2379266, the closest analogue] is known, including the following components, mass %:

Portland cement	14,0-18,0,		
expanded polystyrene	0,5-1,0,		
basalt fiber	0,2-0,3,		
saponified wood resin	0,01-0,015,	plasticizing additive C-3	0,01-0,015,
polyacrylamide	0,01-0,015,		
lignopan B-2	0,01-0,015,		
expanded vermiculite of			
fraction 5-10 mm	67,0-73,0,	water	the rest.

The disadvantages of D3 are: the multi-component nature of the raw material composition with unfavorable environmental characteristics and, as a consequence, the complexity and high energy intensity of the technological process. In addition, the disadvantages of D3 are that the large diameter basalt fiber is difficult to mix into a mixture of cement and sand, so it takes a long time to obtain a homogeneous mixture, which is technologically and economically unprofitable. The main disadvantage of D3 is the lack of indication of density, which is the main characteristic of lightweight concrete.



The objective of the invention is to eliminate the shortcomings of D3 and expand the raw material base.

The stated problem is solved by the fact that a composition for the production of lightweight concrete is proposed, including Portland cement, expanded vermiculite, superplasticizer and water, according to the invention, additionally contains ground granulated blast furnace slag of fraction 5-20 mm, dihydrate gypsum rock of fraction 5-20 mm, coreless silicon carbide fiber and mineral-organic porous filler in the following ratio of components, wt.%:

Portland cement	12,0
Ground granulated blast furnace slag of 5-20 mm fraction	30,0
Dihydrate gypsum stone of fraction 5-20 mm	10,0
Coreless silicon carbide fiber	2,0
Mineral-organic porous filler	36,4
Superplasticizer based on sodium polymethylene naphthalene sulfonate	0,6
Water	9,0

The mineral-organic porous filler contains the following components, by weight:

50.0% expanded vermiculite, 5-10 mm fraction

50.0% ASPM-500 aluminosilicate microspheres

M400 Portland cement is used as the mineral binder.

Ground granulated blast furnace slag of fraction 5-20 mm contains 27-38% SiO₂, 7-12% Al₂O₃, 34-43% CaO, 7-15% MgO, 0.2-1.6% Fe₂O₃, 0.15-0.76% MnO and 1.0-1.9% other substances. Ground granulated blast furnace slag forms a high proportion of high strength calcium silicate hydrate (CSH). Using the specified fraction of ground granulated blast-furnace slag promotes good concrete mix flow. Finer and coarser fractions of ground granulated blast-furnace slag impair the concrete structure.

Dihydrate gypsum stone of fraction 5-20 mm (with CaSO₄x2H₂O content of 95% according to GOST 4013-2019) is introduced as a component with increased water demand and setting speed compared to cement, which reduces the impregnation and swelling of expanded vermiculite grains and accelerates the hardening of the composite binder.

The use of coreless silicon carbide fiber as a fine reinforcing filler increases the strength of concrete and contributes to improving the mechanical strength of structural concrete elements, i.e., reducing possible cracks and crevices. The key feature of coreless silicon carbide fibers is their ultra-fine microstructure, which imparts high strength. The diameter of the coreless silicon carbide fiber used in the claimed composition is 11-15 mm.

A mixture of the following is used as a mineral-organic porous filler:



- mineral filler – coarse-grained expanded vermiculite (grain size 7 to 10 mm, grade 100 according to GOST 12865-7). Expanded vermiculite has excellent thermal and sound insulation properties, is non-toxic, and does not rot. Its unique technical characteristics include temperature resistance, fire resistance, reflectivity, and chemical inertness. Vermiculite is an environmentally friendly and biologically stable product. It does not emit any gases at elevated temperatures, which occurs during fires, a significant advantage over other known materials.

- organic filler - aluminosilicate hollow microspheres (ASPM) according to TU 5717-001-11843486-2004 - glass-crystalline aluminosilicate balls that are formed during high-temperature flare combustion of coal. They are hollow, nearly perfectly shaped silicate spheres with a smooth surface, ranging in diameter from 10 to several hundred micrometers, averaging about 100 mm. Their walls are solid and nonporous, with a thickness of 2 to 10 mm. They have a melting point of 1400-1500 °C and a density of 580-690 kg/m³. The interior of the particles is filled primarily with nitrogen and carbon dioxide.

The mineral-organic filler is obtained by simple mechanical mixing of the components.

The introduction of a superplasticizer based on sodium polymethylene naphthalene sulfonate has a strong liquefying effect on the concrete mixture, which in turn affects the fluidity of the cement without reducing the strength of the concrete.

The introduction of water into the concrete mixture in the amount of 9.0 wt.% according to GOST 23732-2011 is optimal, since in this case maximum mobility is ensured without reducing strength.

The composition of lightweight concrete according to the invention requires the use of accessible and inexpensive materials that have a minimal harmful impact on the environment.

The technology for obtaining the claimed composition is as follows. Table 1 shows the composition of the raw mixture:

Table 1

№	Components	Number of components, wt.%		
		Example 1	Example 2	Example 3
1	Portland cement	25,0	12,0	30
2	Ground granulated blast furnace slag of 5-20 mm fraction	25,0	30,0	30,0
3	Dihydrate gypsum stone of fraction 5-20 mm	5,0	10,0	-



4	Coreless silicon carbide fiber	9,0	2,0	10,0
5	Mineral-organic porous filler	20,0	36,4	12,0
6	Superplasticizer based on sodium polymethylene naphthalene sulfonate	0,4	0,6	0,8
7	Water	15,6	9,0	17,2

Portland cement and a superplasticizer based on sodium polymethylene naphthalene sulfonate are loaded into a forced-mix mortar mixer according to the recipe, mixed for 15-20 seconds, then ground granulated blast furnace slag of 5-20 mm fraction, dihydrate gypsum rock of 5-20 mm fraction, coreless silicon carbide fiber (previously chopped into pieces of 5 to 10 mm in size) and water are added, mixed for 30 seconds. The mixture and porous aggregate are then fed into a special continuous-flow container with a rotating auger at 100-120 rpm, which evenly presses the porous aggregate into the concrete mix. The resulting mixed mixture is poured into 10x10x10 cm molds, which are pre-cleaned and lubricated with machine oil, and then fed to a vibrating table, where they are vibrated for 3-5 seconds. After this, the forms are autoclaved for 12 hours at a pressure of 1.2 MPa and a temperature of 160-180°C.

After autoclave treatment, the samples are stripped. Each sample is then weighed and its linear dimensions are measured.

Testing of samples of the compositions according to the claimed invention is carried out in accordance with the requirements of GOST standards and testing methods for construction mixtures and materials. The physical and mechanical properties of the samples are presented in Table 2.

Table 2

Physical and mechanical properties	Compositions			
	1	2	3	D3
Average density, kg/m ³	850	784	840	-



Compressive strength, MPa	6,82	8,79	6,24	2,0
Thermal conductivity coefficient, W/(m ² °C)	0,19	0,16	0,21	-
Water absorption , %	2,0	1,2	1,8	-

- Thus, compared to D3, the declared composition of the concrete mixture, despite the reduced consumption of binder (savings of up to 30% compared to D3 and 60% compared to D2), surpasses it in the following parameters:

- compressive strength up to 8.79 MPa;
- density - 784 kg/m³;
- thermal conductivity of 0.16 W/(m² 0C);
- water absorption - 1.2%.

From the resulting raw mix, it is possible to prepare a variety of concrete products—blocks, panels, and beams of various sizes and configurations.

Invention formula

A composition for producing lightweight concrete, including Portland cement, expanded vermiculite, a plasticizing additive and water, characterized in that it contains a superplasticizer based on sodium polymethylene naphthalene sulfonate as a plasticizing additive, and additionally contains ground granulated blast furnace slag of a fraction of 5-20 mm, dihydrate gypsum rock of fraction 5-20 mm, coreless silicon carbide fiber and mineral-organic porous filler in the following ratio of components, wt.%:

Portland cement	12,0
ground granulated blast furnace slag of fraction 5-20 mm	30,0
dihydrate gypsum stone of fraction 5-20 mm	10,0
coreless silicon carbide fiber	2,0
mineral-organic porous filler	36,4



superplasticizer based on sodium polymethylene naphthalene sulfonate	0,6
water	9,0
The mineral-organic porous filler contains the following components,	
wt. %: expanded vermiculite, fraction 5-10 mm	50.0
microspheres: aluminosilicate ASPM-500	50,0.

References:

1. Yusupov, H. V., Karimov, G. U., Saidmurodova, S. M., & Mukhammadiev, I. (2023). IMPROVING THE EFFICIENCY OF CEMENT WITH LOW WATER DEMAND. *JOURNAL OF ENGINEERING, MECHANICS AND MODERN ARCHITECTURE*, (2), 155-160.
2. Постановлении Президента Республики Узбекистана ПП-4335 23.05.2019
3. ГОСТ 12865-67 Вермикулит вспученный от 12 апреля 1967.
4. Баулин Д.К. Междуетажные перекрытия из легких бетонов. М., Стройиздат, 1974, 216 с.
5. Бурлаков Г.С. “Технология, изделий из лёгкого бетона”. М., 1986. Бужевич Г. А легкие бетоны на пористых заполнителях. Москва 1970 г.
6. Матёкубов, Б. П., & Саидмуродова, С. М. (2022, August). КАМ СУВ ТАЛАБЧАН БОҒЛОВЧИ АСОСИДАГИ ВЕРМИКУЛИТЛИ ЕНГИЛ БЕТОНЛАР ТЕХНОЛОГИЯСИНИ ҚЎЛЛАНИЛИШИ. In *INTERNATIONAL CONFERENCES* (Vol. 1, No. 15, pp. 103-109).
7. Matyokubov, B. P., & Saidmuradova, S. M. (2022). METHODS FOR INVESTIGATION OF THERMOPHYSICAL CHARACTERISTICS OF UNDERGROUND EXTERNAL BARRIER STRUCTURES OF BUILDINGS. *RESEARCH AND EDUCATION*, 1(5), 49-58.
8. Pulatovich, M. B., & Muzaffarovna, S. S. (2022). METHODS FOR INVESTIGATION OF THERMOPHYSICAL CHARACTERISTICS OF UNDERGROUND EXTERNAL BARRIER STRUCTURES OF BUILDINGS. *ISSN 2181-3191 VOLUME 1, ISSUE 5 AUGUST 2022*, 202259.
9. Karimov, G. U. (2021). Energy efficient binder of low water demand with modified mineral additives based on local available components. In *Euro-Asia Conferences* (Vol. 4, No. 1, pp. 106-109).
10. Karimov, G. U. (2021). Energy efficient binder of low water demand with modified mineral additives based on local available components. In *Euro-Asia Conferences* (Vol. 4, No. 1, pp. 106-109).



11. Karimov, G., & Bakhriyev, N. (2018). RESEARCH ON THE DEVELOPMENT OF ENERGY-EFFICIENT BINDERS FOR MODERN CONSTRUCTION. *Problems of Architecture and Construction*, 1(2), 61-63.
12. Yusupov, X. V., Karimov, G., Saidmurodova, S. M., & Zayniyevich, I. F. (2024). KAM SUV TALABCHAN SEMENTLARNING ZAMONAVIY MUAMMOLARI. *Miasto Przyszłości*, 44, 231-234.

