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Development of building structures with individual characteristics taking into account the conditions of Uzbekistan

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Abstract: The climatic conditions of Uzbekistan (cold winters, very hot summer days) require building materials with high energy efficiency. This article presents the possibilities of creating energy-efficient, sustainable and local raw materials-based building structures, taking into account the natural-climatic and geological conditions of Uzbekistan. Aerated concrete blocks are widely used in the construction industry as a lightweight, heat-retaining and relatively inexpensive material. In particular, ways to improve the physical, mechanical and thermal properties of aerated concrete blocks by adding steelmaking slag (SMS) and waste quartz sand are studied. Its strength can be increased and the cost of raw materials can be reduced by using local industrial waste. The study improved the physical, mechanical and thermal properties of aerated concrete blocks using steelmaking slag (SMS) and waste quartz sand. As a result, it was found that the addition of these materials improves the strength of aerated concrete by 12-13%, and thermal insulation by 1-1.5%. Also, the use of waste helps reduce the cost of raw materials and increase environmental efficiency. The results of the study confirm the effectiveness of this technology in the development of energy-efficient and affordable building materials in Uzbekistan. Based on experimental data, new composite compositions were developed and their effective results in terms of thermal conductivity, density and strength were demonstrated.

Keywords: aerated concrete, steel slag, waste sand, thermal conductivity, density, strength, D600 grade

1. Introduction

Today, at a time when the process of design and construction of energy-efficient buildings in the world is developing rapidly, the demand for energy-efficient and cost-effective building materials is growing. Positive changes in the construction industry in our country and the huge creative work around us, along with the need to create and apply new equipment and technologies, lead to an increase in costs for the construction and operation of buildings [1-3].

In this regard, in the process of designing and construction of energy-efficient buildings, the issue of covering the outer walls with effective thermal insulation materials or adapting the outer wall structure to modern thermal insulation requirements is important in the process of their future use.

Currently, research is being conducted in developed countries aimed at creating external barrier structures from aerated concrete as energy-efficient and environmentally friendly materials. In this regard, including aerated concrete to model its optimal porous structure to meet the requirements of thermal protection and strength, improve its structure by adding special chemical additives to the concrete mix to create effective external barrier structures from aerated concrete, substantiate the requirements for energy-efficient building exterior walls, One of the urgent tasks is to develop appropriate technological solutions that provide the necessary properties, as well as structures with high resistance to thermal conductivity [4-8].

In developed countries such as Germany, USA, Japan, Sweden, Austria, France, Finland, Russian Federation, attention is paid to the production of cost-effective aerated concrete using industrial waste, increasing its properties such as thermal insulation, strength, moisture permeability [9-11]. As a result, along with the utilization of industrial waste, it has a positive effect on increasing the economic efficiency of aerated concrete.

Particular attention is paid to the creation of energy-efficient building structures and the introduction of new technologies, the development of modern building materials industry using local products, reducing the cost of construction products and reducing energy consumption in the operation of buildings and structures.

In this regard, the President of the Republic of Uzbekistan On the basis of large-scale reforms in the construction industry under the leadership of Sh.M.Mirziyoyev, on May 23, 2019 No. Presidential decree (PD) PQ-4335 “On additional measures for the accelerated development of the construction materials industry”, February 20, 2019 No. PQ-4198 “On radical improvement and complex Development Resolutions” were adopted. This is aimed at ensuring high rates of production and export of competitive products from local raw materials in the country, as well as modernization of enterprises, technical and technological deepening of structural changes in the building materials industry.

In the production of building materials from aerated concrete, it is advisable to study in detail the issue of adding them to industrial waste as a filler. Therefore, today, research work is underway to include a mixture of ash "strip" and quartz sand, which is separated as industrial waste during the operation of the foundry-mechanical plant under JSC “Uzbekistan Railways”. The inclusion of the above and other ty SMS of industrial waste in the concrete during the production of aerated concrete blocks, first of all, saves waste processing (utilization), binder (cement), increases the operational properties of the structure.

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In recent years, the demand for building materials in Uzbekistan has been increasing sharply. At the same time, existing materials do not always meet local climate, seismic activity and environmental requirements. The quality of materials used in construction, especially their ecological, economic and technical efficiency, is one of the pressing issues today. In particular, structural elements intended for multi-storey buildings, industrial buildings and social structures should not only be durable, but also lightweight, energy-efficient and have a long service life. In this regard, aerated concrete blocks are considered an alternative solution. Aerated concrete blocks are distinguished by their light weight, low thermal conductivity and ease of processing. At the same time, increasing their strength and thermal insulation properties is an important task. For this purpose, the article studies the physical, mechanical and thermal properties of aerated concrete blocks using steelmaking slag and waste quartz sand, and develops optimal compositions.

2. Research methodology

Many studies have been conducted on the use of secondary products in aerated concrete products, in which it was stated that steel smelting slag has a binding property [14], and it was stated in the studies that it is effective in replacing cement. Taking this into account, we will consider designing the composition of aerated concrete using steel smelting slag in an amount of 10-20 percent in accordance with the studies in [13, 15].

Since the size of the steel smelting slag fractions is 10-20 mm, a “SHLM-100” ball mill was used for grinding. Then, it was sieved through a No. 008 sieve and added to the cement to form the mixture. Information on the chemical oxides and their content in the slag and cement is given in Table 1.

Table 1

Chemical composition of iron smelting slag

Name	Calcium oxide	Silicon oxide	Iron oxide	Manga-nese oxide	Alumi-num oxide	Magne-sium oxide	Phos-phorus oxide	Calcium fluoride
Oxide name	CaO	SiO_2	FeO	MnO	Al_2O_3	MgO	P_2O_5	CaF_2
Amount in slag	57,3	21,95	3,85	4,9	8,9	2,3	1,4	6,7
Amount in cement	64,9	21,9	3,6	1,5	4,8	1,6	-	-

It can be concluded from Table 1 that the silicon and calcium oxides in the slag, as well as in cement, increase the binding properties of the mixture by forming an active interaction reaction with water. At the same time, since the chemical oxide composition of waste slag and cement is 80-85% similar, it can be used as a cement substitute.

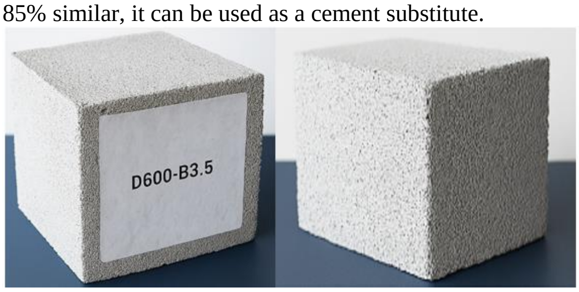

Figure 1. External view of D600 aerated concrete sample

The composition and viscosity of the aerated concrete mixture using steelmaking slag were developed using computational and experimental methods developed in accordance with the studies in [16], based on the data of the mathematical method of planning experimental studies, and samples in the form of cubes of the D600 brand with dimensions of 100x100x100 mm were prepared in laboratory conditions (Fig. 1). The samples were subjected to normal hardening conditions at a temperature of 20 °C with a relative humidity of 95 percent for 7 and 28 days.

Cubes were cast from the prepared aerated concrete mixtures and placed in a special room for storage in humid conditions, and after 28 days the physical and mechanical properties of the blocks were determined.

The following formulas were used in the experiments:

Density (ρ):

$$\rho = \frac{m}{V} \quad (1)$$

where:

m – mass of the dried sample (kg)

V – volume of the sample (m^3)

Compressive strength — strength (σ):

$$\sigma = \frac{F}{A} \quad (2)$$

where:

F – maximum compressive force in the test (N)

A – cross-sectional area of the sample (m^2)

Thermal conductivity (λ):

$$\lambda = \rho \cdot C_p \cdot \alpha \quad (3)$$

where:

ρ – density (kg/m^3)

Cp – heat capacity (J/kg·K), for aerated concrete ≈ 1000 J/kg·K

α – heat dissipation coefficient (m^2/s)

Also, the presence of 85-93% silicon oxide (silica) in the composition of waste quartz sand indicates that it has a unique active chemical and reactive composite properties. The composition of the aerated concrete mixture was prepared in the amounts given in Table 2.

In this case, D600 aerated concrete blocks were prepared in laboratory conditions using steel smelting slag and their strength and calculated thermal conductivity were determined in accordance with the requirements of GOST 10180-2012 using a hydraulic press of the “CD-2000” brand, in accordance with the requirements of KMC 2.01.04-18 “Construction Heat Engineering”.

Table 2

Composition of D600 aerated concrete mix with steelmaking slag for cube preparation in laboratory conditions

S. n.	Components name	Unit of measurement	Quantity
1	Cement	kg	220
2	Steel melting slag	Of cement mass, %	10-20
3	A fine filler	kg	360
4	Lime	kg	10
5	Aluminum powder	kg	0,47
6	Water	l	264
7	Caustic soda	kg	3
8	Sodium sulfate	kg	4,6

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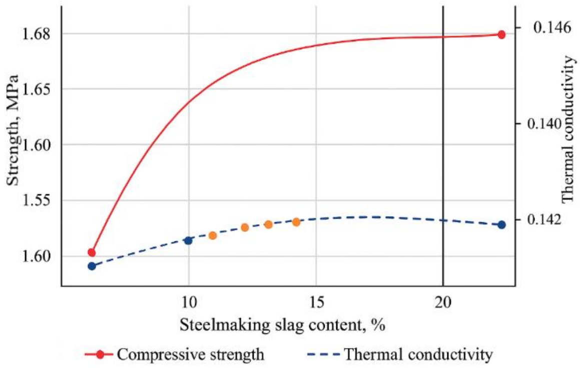

Figure 2. Dependence of the strength and thermal conductivity of aerated concrete on the amount of slag

In the picture above according to the results of laboratory research, the strength and thermal conductivity properties of aerated concrete using steel melting slag are shown in

It can be seen from this graph that the amount of slag was added to the composition of aerated concrete in the amount of 10%, 10-15% and 15-20% of the cement mass, and it was compared according to the samples prepared by the composition of industrial enterprises. When the amount of slag in the composition of aerated concrete is up to 10% of the cement mass, it was observed that the strength of the blocks and the calculated thermal conductivity improved by 0.1-0.5%. When the amount of slag is 10-15%, the average density is 3-6%, the calculated thermal conductivity is 2-4.5%, and the strength is improved by 7-12%. It was also observed that when the amount of slag is 15-20%, the average density increases by 6-9% and strength by 12-13%, the calculated thermal conductivity decreases by 1-1.5%. Therefore, according to research results, it is advisable to choose slag in the amount of 10-15 percent of the cement mass. Here, after determining the optimal amount of steel melting slag for the preparation of aerated concrete mixture, a mutual comparative analysis of the physical and mechanical properties of the samples prepared in the laboratory according to this composition and the composition of the production organization is presented in Figure 3.

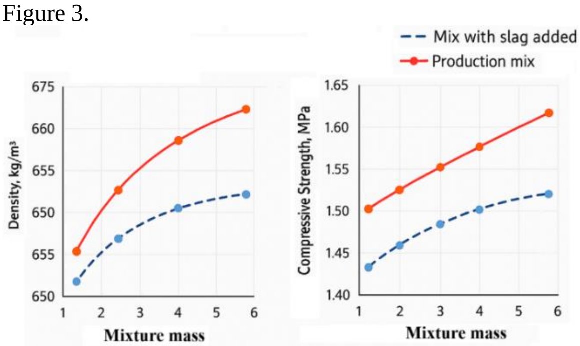

Figure 3. The results of the comparative analysis of the compositions used in industrial enterprises and slag used

The comparative analysis in the graph shows that slag, in addition to having cement-substituting properties, also serves to increase the strength of aerated concrete due to its higher density than cement. This is of great importance for increasing the efficiency of using steelmaking slag in the production of aerated concrete.

All experiments were carried out with a small amount of aerated concrete samples. At the same time, it is recommended to use fine-grained compositions presented in studies [11, 12, 15] in the composition of aerated concrete in which slag is used. This is because fine particles help the mixture to rise uniformly during the process of aerated concrete expansion.

The amount of filler particles in the composition is of great importance in the production of structural and thermally insulating aerated concrete blocks. Taking this into account, in this dissertation, studies were conducted on the introduction of quartz sand into the composition of aerated concrete. It is scientifically proven that adding quartz sand to aerated concrete is one of the most effective fillers [8, 9, 10]. Considering that adding quartz sand to concrete increases the cost of blocks, it is important to produce aerated concrete blocks using waste quartz sand. The appearance of the added waste quartz sand and the samples made from it are shown in Figure 4.

Figure 4. Appearance of waste quartz sand and samples

At the next stage, the effect of waste quartz sand on aerated concrete strength and calculated thermal conductivity indicators was studied. The results of this study are presented in Figure 5.

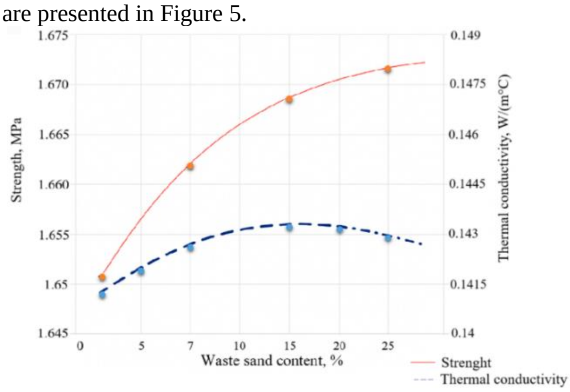

Figure 5. Dependence of the strength and thermal conductivity of aerated concrete on the amount of waste quartz sand

According to the above graph, the amount of waste quartz sand was added to aerated concrete in the amount of 10%, 10-20% and 20-30% of the sand mass, and it was compared according to the samples prepared by the composition of industrial enterprises. When the amount of waste quartz sand in aerated concrete is up to 10% of the cement mass, it was observed that the strength of the blocks and the calculated thermal conductivity improved by 0.6-1.0%. When the amount of waste quartz sand is 10-20%, the average density is 5-7%, the calculated thermal conductivity is 3-5.5%, and the strength is improved by 8-11%. Also, when the amount of waste quartz sand is 12-30%, the average density increases by 7-11% and strength by 11-13%, and the calculated thermal conductivity deteriorates by 1.5-2.5%. Therefore, according to the results of the study, it is advisable to select waste quartz sand in the amount of 10-15% of the sand mass.

Then, aerated concrete blocks were produced according to the amount of waste quartz sand determined above, and their physical and mechanical properties were compared with blocks of the same composition produced at industrial enterprises. The results of the comparative analysis are presented in the graph in Figure 6.

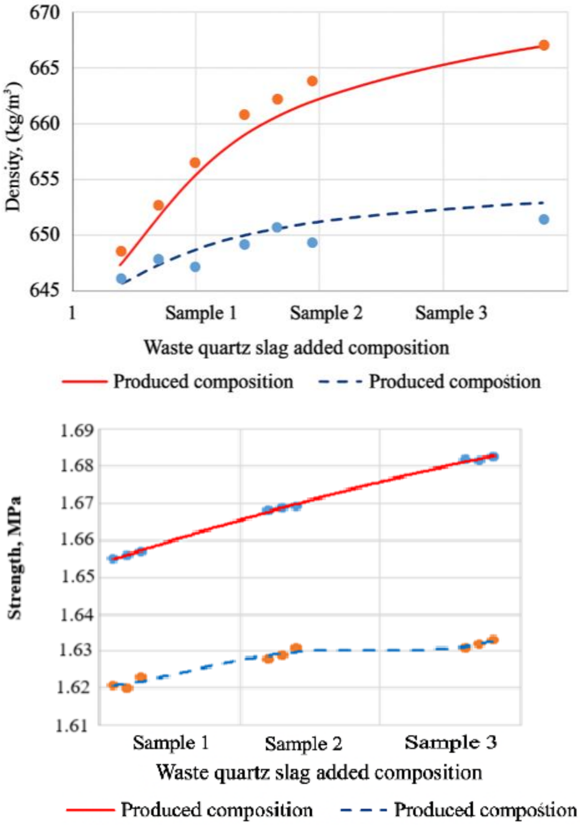

Figure 6. Physical and mechanical properties of waste quartz sand and aerated concrete samples offered by industrial enterprises

From the graph above, it can be seen that due to the small dispersion of waste quartz sand particles, the pores in aerated concrete blocks are evenly distributed in size. The physical and mechanical properties of the prepared samples show that the average density of the sample using waste quartz sand was 651 kg/m3 and the strength was 1.645 MPa, while the average density of the samples prepared by the composition of industrial enterprises was 646 kg/m3 and the strength was 1.62 MPa. It was found that the content with the addition of waste quartz sand improved by 2-4.5 percent compared to the content in industrial enterprises.

On this basis, the first study of aerated concrete composition using slag and waste quartz, in which the study of the physical and mechanical properties of the blocks when they are combined, is studied in the next chapter.

3. Results and Discussion

Due to the calcium and silicon oxides contained in steel smelting slag and waste quartz sand, chemically active bonds occur in the composition of aerated concrete. This enhances the bonding properties without the need for additional cement. The fine particles of sand also serve to evenly distribute the pores during the expansion process of aerated concrete.

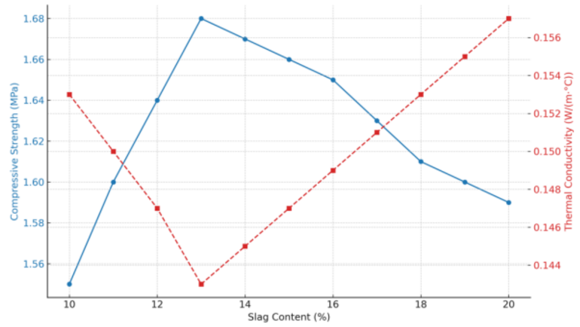

Figure 7. Effect of SMS content on strength and thermal conductivity

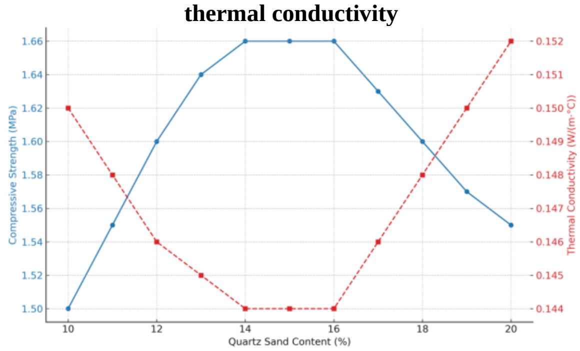

Figure 8. Effect of quartz sand content on aerated concrete properties

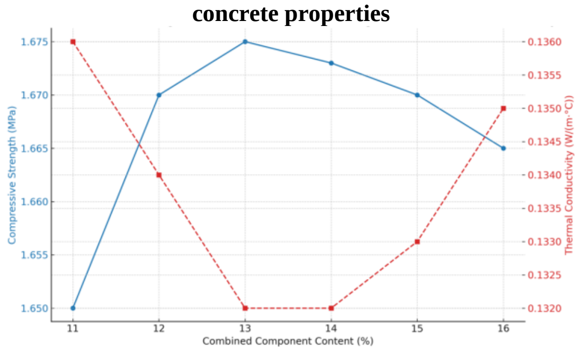

Figure 9. SMS (11–13%) + waste quartz sand (14–16%) when added together

Table 3

Properties of aerated concrete with optimal composition

Components	Stability (MPa)	λ (W/(m·°C))	Density (kg/m³)
Ordinary aerated concrete	1,51	0,147	630–640
Only SMS (12%)	1,68	0,143	670
Quartz sand only (15%)	1,66	0,144	665
SMS + quartz sand	1,675	0,132	670–672

4. Conclusion

The article reviews research on the development of energy-efficient and sustainable building materials suitable for the specific climatic conditions of Uzbekistan. By adding steelmaking slag (SMS) and waste quartz sand to the composition of aerated concrete, its strength, thermal insulation and economic efficiency were increased. Experimental results showed that the strength of aerated concrete blocks made using SMS (12%) and waste sand (15%) is 1.675 MPa, thermal conductivity is 0.132 W/(m

°C), and density is 670-672 kg/m³. These indicators indicate that they have higher quality characteristics compared to traditional aerated concrete.

The study shows that the use of local industrial waste not only reduces the cost of building materials, but also mitigates environmental problems. This approach can be the basis for the introduction of energy-efficient and sustainable technologies in the construction sector of Uzbekistan. In the future, it is necessary to study the long-term performance properties of these materials and introduce their production on a large scale.

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