Optimization of physical and mechanical properties of non-autoclaved aerated concrete based on industrial waste

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Abstract. This article presents the results of experimental research on the parameters of aerated concrete porosity strength properties and properties based on industrial waste. The structurally optimal amount of water was determined, reflecting the physical-mechanical, thermal-technical properties of the outer wall structures based on aerated concrete.
The test results were carried out in research laboratories using aerated block constructions with high porosity and optimal composition, and improved technological solutions for autoclaved aerated concrete were developed.
Study of changes in the properties of aerated concrete with the addition of waste quartz sand and steel smelting slag; optimization of aerated concrete composition by mathematical regression method and determination of physical and mechanical properties; the results of the research on automating the calculation of the proposed composition of aerated concrete and the amount of industrial waste according to its brand are given.

1 Introduction

In recent years, the sharp increase in the housing stock, and the increase in multi-story and single-family construction based on extensive growth, necessitates the need for efficient construction materials that combine cost reduction and high technical and economic indicators.

In most cases, when using traditional raw materials to produce aerated concrete, construction is carried out based on the regulatory requirements of thermal engineering. Compared with modern standards, the thermal conductivity is 3.5 times better [1].

Satisfying the modern thermal technical requirements of brick, wood, and concrete blocks leads to a significant thickening of wall structures and an increase in the weight of buildings, leading to a decrease in earthquake resistance and the economic efficiency of construction [2].

It should be noted that the creation of multi-layer constructions using modern heat-insulating materials is not always justified [3] because the service life of buildings built using them can significantly increase the service life of these materials [4]. In many cases

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[5], using such buildings and structures improves their properties such as fire resistance is not satisfactory enough. Several other factors can prevent the constructions from changing their dimensions [6].

Expanding the base of building materials in a society based on new technologies and preventing the spread of harmful substances by processing industrial wastes that strongly impact human health is one of the most urgent issues facing humanity [7]. At the same time, the re-combination of oxides contained in industrial waste makes it possible to use it as a secondary product. In the production of modern construction materials using industrial waste, it is an important task to reduce the weight of the material, taking into account earthquake measures. Therefore, it is possible to include industrial waste in aerated concrete and expand the base of raw materials and reduce the product's price [8].

Covering binders and silicon oxide additives with secondary materials in developing aerated concrete composition allows, first of all, to reduce the impact of harmful substances from waste on the environment and achieve economic efficiency [19].

Also, many technological factors affect its properties when forming the structure of aerated concrete. These factors include various structure-forming chemical additives that significantly change the quality of aerated concrete without an autoclave [10].

The influence of technological factors such as the temperature of the water, density of the mixture, and sample storage conditions for the formation of the mixture as a research object was studied [11].

When preparing the aerated concrete mixture, the temperature of the water greatly influences the formation of its porous structure [12]. As the temperature of the aerated concrete mixture rises, the expansion process accelerates [13]. In this process, the formation of gas increases to the required level in a certain period. Due to the lightness of the gas bubbles, they tend to rise faster; as a result, the rise of the mixture accelerates, and at the same time, the process of solidification of the mixture begins [14].

2 Research methods and tools

Experimental studies were carried out using non-standard methods developed by scientific research experts according to generally accepted standards, laboratory tests using fillers based on industrial waste.

Study of the normal thickness of non-autoclaved aerated concrete blocks The VS-GEO-NDT Suttard viscometer was performed on a laboratory instrument (Figure 1).

Fig. 1. VS-GEO-NDT Suttard viscometer laboratory instrument

Experimental research and data processing were carried out following GOST 23789-2018 in the following sequence [15]:

1. Several mixtures were prepared according to the ratio of the water amount to the cement mass, respectively.
2. The VS-GEO-NDT Suttard viscometer was mounted horizontally.
3. The mixture was slowly placed in the cylinder and raised after the cylinder was filled.
4. The diffusion diameter of the mixture was determined, and the thermal conductivity was checked accordingly.

Aerated concrete samples were tested for strength according to GOST 10180-2012 with the help of a "CD-2000" brand hydraulic press on the method of determining the strength of concrete [16].

Determination of the strength of aerated concrete samples using a hydraulic press was carried out in the following sequence [17]:

1. 100x100x100 mm cubes of aerated concrete samples were installed in the press in turn;
2. Samples were gradually loaded with a continuously increasing force and lost their previous state;
3. Maximum breaking strength values for each sample were recorded;
4. The average breaking strength of several samples and its brand were determined.

The compressive strength of aerated concrete is calculated with an accuracy of 0.1 MPa according to the following formula:

$$R = \left(\frac{P}{F}\right) \cdot \alpha \qquad (MPa)$$

P is breaking force, kg; F is sample surface, cm^2; α is scaling coefficient; this coefficient is α=0.95.

The necessary values of the heat transfer coefficient of energy-efficient civil buildings' external wall constructions for different climatic conditions of the Republic of Uzbekistan were implemented using "Base" computer programs.

The necessary values of the heat transfer coefficient of energy-efficient civil buildings' external wall constructions for the Republic of Uzbekistan climatic conditions were implemented using the "Base" computer programs (Figure 2).

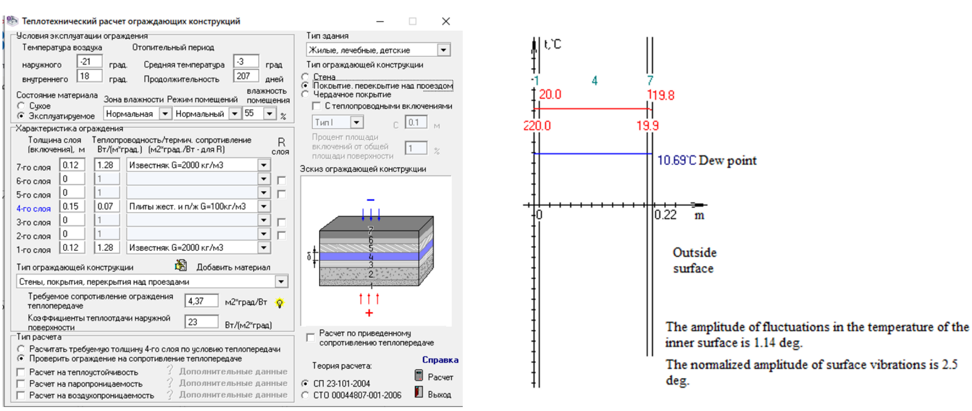


Fig. 2. Thermal technical results in "Base 10.0" computer program

Using the computer program "Base 10.0", the determination of thermal and technical properties of aerated concrete samples was carried out in the following sequence:

Based on the regulatory requirements of "Construction thermal engineering", layers and regional information were entered;

The specified material type and its thermal conductivity coefficient are entered;

Calculations were performed, prescribed graphic and written reports were obtained, and analysis was performed.

Experimental studies were conducted using filling materials based on industrial waste and laboratory tests using non-standard methods developed by scientific research experts according to generally accepted standards.

3 Study of physical, mechanical, and heat-technical properties of aerated concrete and determination of criteria parameters of structure of materials structure

In the study of the effect of water temperature on the mixture, when preparing samples of 40X40X160 mm and 100X100X100 mm, the water temperature was taken at 20^{0}C, 40^{0}C, and 60^{0}C.

Table 1 shows the study results of the physical and mechanical properties of aerated concrete.

Table 1. Composition and physical-mechanical parameters of aerated concrete using steel smelting slag and industrial waste quartz sand

№	t, °C	S/W	Steel melting slag, %	Waste sand, %	Spread, sm	Moisture, %	ρ, g/sm^3	P, MPa
1	20	0.44	11-13	14-16	27	5	0.647	1.64
2	20	0.44	11-13	14-16	27	5	0.604	1.647
3	20	0.44	11-13	14-16	27	5	0.587	1.65
4	40	0.44	11-13	14-16	29	5	0.630	1.656
5	40	0.44	11-13	14-16	29	5	0.622	1.65
6	40	0.44	11-13	14-16	29	5	0.606	1.66
7	60	0.44	11-13	14-16	29	5	0.683	1.67
8	60	0.44	11-13	14-16	29	5	0.680	1.675
9	60	0.44	11-13	14-16	29	5	0.664	1.68

The results of the conducted research showed that the water requirement of the aerated concrete mixture changes depending on its temperature. That is, if the temperature rises, the water demand of the mixture components decreases; as a result, the mixture becomes plastic. If the water temperature in the mixture was 20 °C, the spread on the Suttard viscometer was 27 cm, and at 60 °C, it was 29 cm.

The expansion height of the aerated concrete composite mixture prepared using industrial waste sand varies depending on the mixture's temperature. As the temperature of the water in the mixture increases, the rise of the aerated concrete mixture becomes higher. The water temperature in the aerated concrete is 20°C, and the expansion of the aerated concrete begins. The maximum expansion of the mixture occurs at the water temperature in aerated concrete at 60°C.

As the mixture's temperature increases to 40-60 °C, the expansion process continues more rapidly, and the process of merging small pores in the aerated concrete is observed. The high temperature of the water in the mixture causes rapid movement of the molecules of the binder, as a result of which the hydration and binding process of the cement is accelerated, the capillary cracks in the resulting mixture are reduced, and the cracks are prevented. This, in turn, creates the basis for the improvement of the physical and mechanical properties of the structure, as well as for its durable and long-term service.

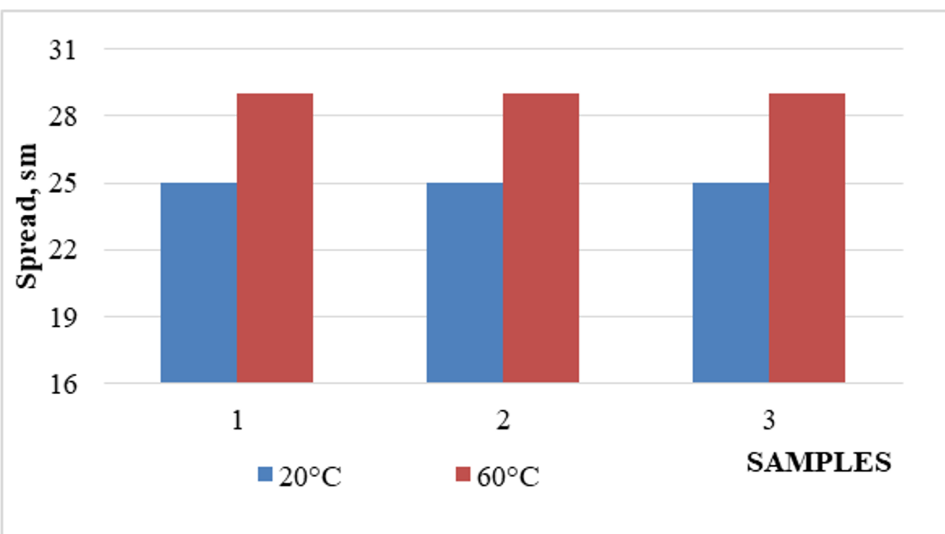
As the amount of small fillers in the mixture increases, the density of aerated concrete increases. Naturally, due to the weight of waste slag, gas-forming substances accelerate their chemical reaction at high temperatures, and aluminum powder in the composition accelerates the process of gas formation. In this process, similar to aerated concrete with low density, the molecules in the binder quickly react with other substances. After that, the mixture is poured into the molds, and the rising process is observed. The part that protrudes from the mold is trimmed off and stored in a laboratory with 95 percent humidity. In this case, small cracks do not appear in the samples.

The physical and mechanical properties of aerated concrete under study are presented in Table 2.

Table 2. Physical and mechanical properties of D600 aerated concrete

№	Spread, sm	ρ, g/sm^3	P, MPa	Thermal conductivity, W/(m*^{0}C)	Spread, sm	ρ, g/sm^3	P, MPa	Thermal conductivit, W/(m*^{0}C)
20 °C					**60°C**			
1	25	0.647	1.640	0.144	29	0.683	1.670	0.1444
2	25	0.604	1.647	0.144	29	0.680	1.675	0.1445
3	25	0.587	1.650	0.143	29	0.664	1.680	0.1434

Based on the obtained results, the strength of aerated concrete, density, and thermal conductivity of water temperature were analyzed, and comparative results were obtained (Figure 3).



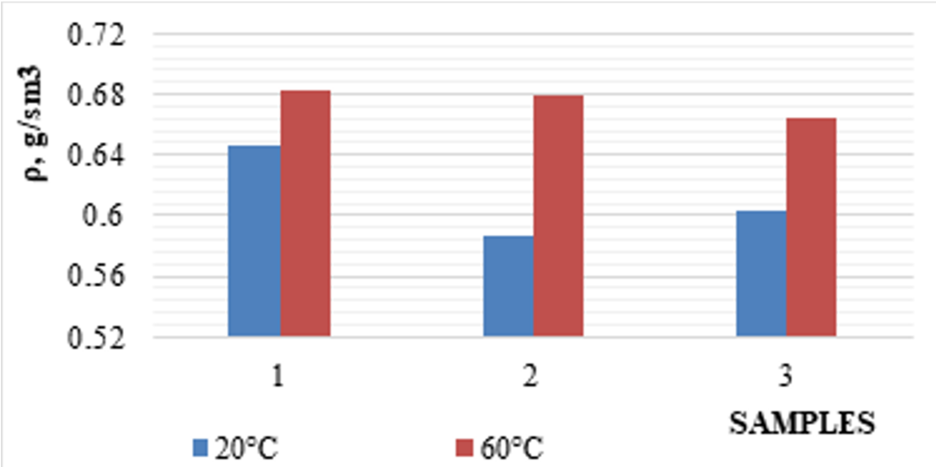
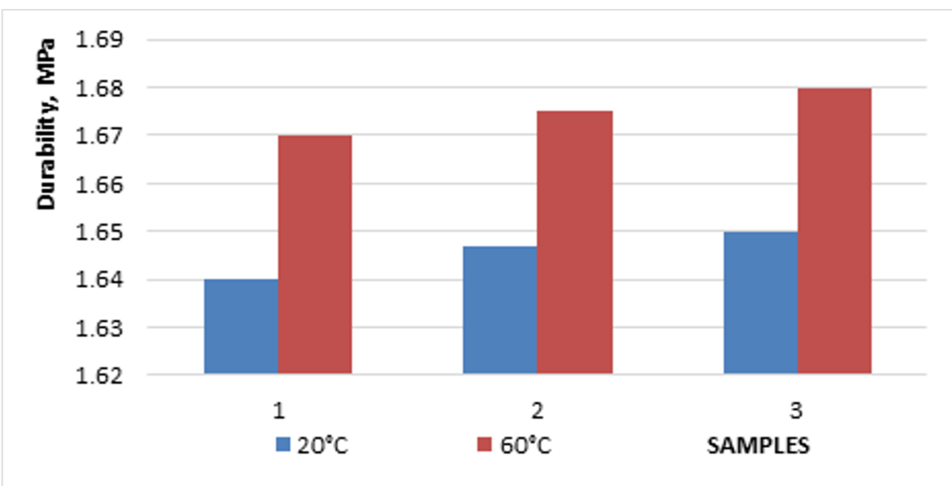


Fig. 3. Comparative graph between spread and density of aerated concrete mixture temperature in Suttard

According to this graph, the maximum values are achieved when the water temperature in the samples is 600C, which, in turn, requires the use of water with a temperature of 56-60^{0}C.

Based on the experimental test results, the dependence of strength and thermal conductivity characteristics on water temperature is presented in Fig. 4.



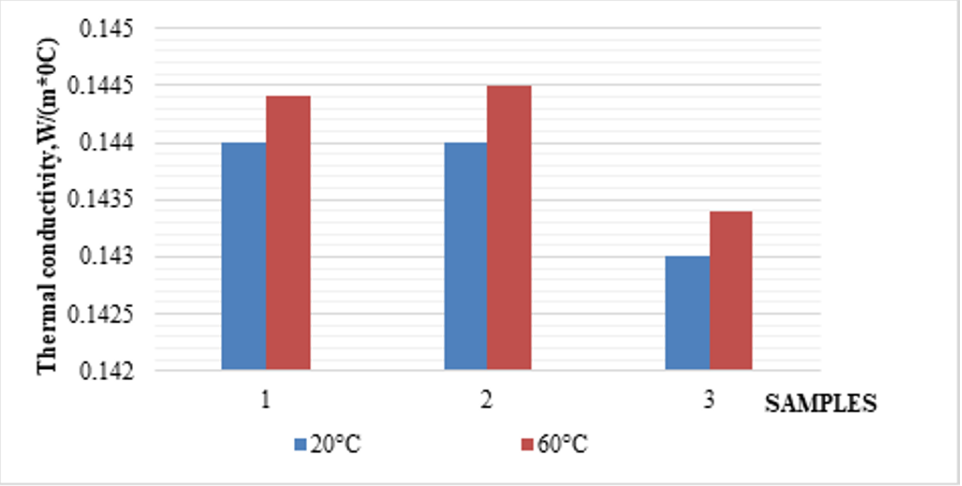


Fig. 4. Dependence of temperature of aerated concrete mixture on strength and thermal conductivity of samples

Based on the experiment's results, along with the composition of the mixture components, the temperature of the water shows its influence on the physical and mechanical properties of aerated concrete compositions. As a result, the water temperature should be around 56-60 °C to obtain low-grade aerated concrete using sand based on industrial waste. In this case, the necessary gas formation process is achieved only at a high temperature of the water mixture [18].

The research results showed that the higher the water temperature in the mixture, the faster the reaction. It should be taken into account that if the water temperature exceeds 60^0C, the strength of the mixture will not be at the specified level, and changes will occur in the process of forming pores, which will hurt the heat transfer properties.

4 Conclusions

1. The normal density of the aerated concrete mixture and its effects on physical and mechanical properties were studied;
2. The influence of aerated concrete from industrial waste on its spreading width, density, strength, and thermal conductivity in Suttard was determined.
3. The samples' actual thermal conductivity and theoretical thermal conductivity were calculated in the modern Base program, and the methodology for determining the territorial measurement units of the thickness of aerated concrete blocks was developed.

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