

Modeling development of optimal composition of non-autoclaved aerated concrete based on industrial waste

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Abstract. This article presents the modern state of energy-efficient residential building exterior wall constructions from aerated concrete, and the main properties of aerated concrete are analyzed. Properties of composite building materials, strength, and heat-technical properties depending on their structure are considered. Also, the analysis of existing problems in obtaining aerated concrete in the Republic of Uzbekistan is presented.

The results of research on the use of industrial waste in aerated concrete have shown that it is appropriate to continue research using physical-mechanical and chemical activation methods for the wide application of secondary filler activation, particularly in construction production.

The modern state of construction of external wall structures of energy-efficient residential buildings from aerated concrete is presented, in which the main properties of aerated concrete are analyzed. Properties of composite building materials, strength, and heat-technical properties depending on their structure are considered. Also, the analysis of existing problems in obtaining aerated concrete in the Republic of Uzbekistan is given.

1 Introduction

In the world of construction practice, the use of energy-efficient building materials and the widespread involvement of lightweight porous concrete in the construction of buildings and structures has been increasing in recent years. In developed countries, including Germany, Finland, Japan, the USA, the Netherlands, South Korea, Austria, Poland, China, the Russian Federation, the Czech Republic, and Turkey, improving the technologies of creating and producing aerated concrete, production of aerated concrete from natural and man-made raw materials, as well as special attention is paid to the production of equipment and additives used to increase the quality [1-4].

In the world, a lot of scientific and research work is being carried out aimed at producing aerated concrete based on waste, thereby ensuring the seismic tolerance, strength, and reliability of buildings and structures[5]. It is one of the important tasks to carry out research aimed at increasing the service life, fire resistance, frost resistance, strength, thermal protection properties, and earthquake resistance of aerated concrete based

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on industrial waste, as well as reducing its price [6].

In construction, the use of effective heat-insulating construction materials with an average density of 500-900 kg/m³ as energy-saving materials and the improvement of its economic efficiency; in this regard, issues of processing industrial waste products are becoming important [7].

The study of technological processes using additional raw materials with specific properties in the purposeful formation of the structure of aerated concrete in advance and the determination of its optimal composition is a matter consisting of the results of theoretical and experimental scientific research. There are many technologies in the world for the production of aerated concrete. However, in our republic, this construction is not as widely used as in developed countries. Expanding the production of aerated concrete without autoclaves in all regions of our country and improving the technology of obtaining gas blocks is an urgent task for the construction industry of Uzbekistan [8].

Today, aerated concrete is one of the most effective thermal insulation materials. The theory and practice of aerated concrete production show that the specific properties of such materials are formed depending on their production method [9-10].

Many scientists in the world, including Ukhova T.A., Kazakov Yu.N., Vilezhagin V.P., Pinsker V.A., Kondratev V.V. , Kurnishev R.A., Elistratkin M.Yu., Donchenko O.M., Sajnev N.P., Sokolovsky L.V., Zhuravlev I.S., Filatov A.N., Novik Yu., Morgun L., Gorlov Yu.P., Volzhensky A.V., Paplavskis Kuryatnikov Yu.Yu., Kara K.A. and others have conducted research and achieved certain scientific and practical results [11-15, 17-21].

In these studies, with the help of mineral and organic additives and plasticizers, research was conducted on various properties of aerated concrete, strength, thermal protection, porosity optimization, and moisture reduction.

2 Research methods and tools

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

The porous structure of aerated concrete blocks was studied with the help of "Thermo Scientific Pascal 240 EVO" mercury porosimeter (Figure 1).



Fig. 1. "Thermo Scientific Pascal 240 EVO"

The "Thermo Scientific Pascal 240 EVO" mercury porosimeter is an automated technical tool that determines samples' porosity and particle size under a pressure of 200 MPa.

Experimental studies and data processing were carried out in the following sequence [11-12]:

1. A vacuum was created for aerated concrete in "Thermo Scientific Pascal 240 EVO" mercury porosimetry. A sample is placed in the resulting vacuum flask, and mercury is added to it.

2. Mercury slowly enters the sample and fills its pores. Then, depending on the total size of the sample, the porosimeter determines its percentage of porosity.

3. After the completion of the experimental research, the data are processed using a special computer program in the established order, and the necessary diagrams are created.

After the laboratory analysis is completed, the computer automatically describes the samples' pore size, mercury penetration, and pressure resistance diagrams.

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

The composition of aerated concrete used in production organizations and gas blocks' physical and mechanical properties were studied. When their indicators are compared with the state standard (GOST-25485-2019 "Acellular concretes. Technical conditions"), existing shortcomings are identified. At the same time, it has been proven based on research that the optimal amount of industrial waste in obtaining the rational composition of aerated concrete: 11-13 percent of steel melting slag and 14-16 percent of waste quartz sand. Also, the factors influencing the increase in the average density and strength of aerated concrete were studied [13-15].

Cube samples were prepared in laboratory conditions according to the content used in production enterprises, and then samples of aerated concrete with added industrial waste were prepared. A comparative analysis of the physical and mechanical properties of the obtained samples is presented in Fig. 2.

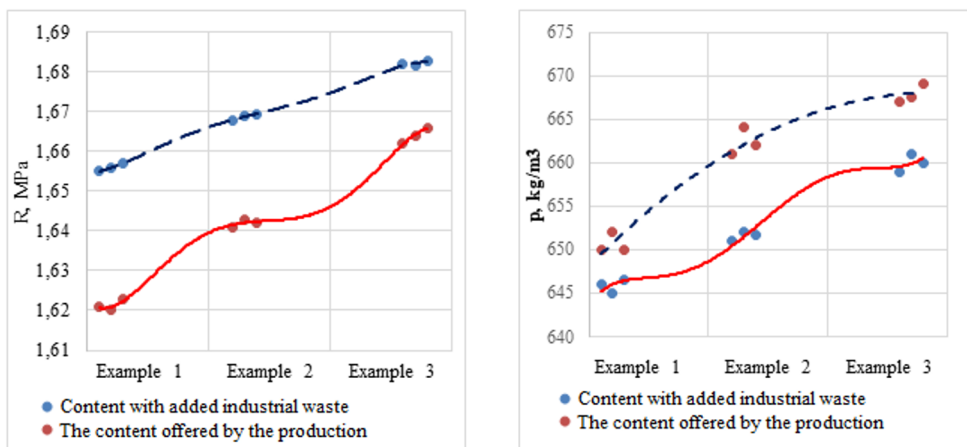


Fig. 2. Strength and density of aerated concrete samples

Compared to the density and compressive strength of the samples prepared according to the composition used in industrial enterprises, it was found that aerated concrete with industrial waste has a higher density, so the strength is also higher (Table 1).

Table 1. Composition of 1m³ aerated concrete mixture of brand D600

№	Components name	Unit of measure	Amount	
			Featured content Content in production	Featured content Content in production
1	Cement	kg	210	245
2	Steel melting slag	kg	21	-
3	Fine filler	kg	312	360
4	Waste quartz sand	kg	49	-
5	Lime	kg	10	10
6	Aluminum powder	kg	0,47	0,47
7	Water	l	264	264
8	Caustic soda	kg	3	3
9	Sodium sulfate	kg	4,6	4,6

Aerated concrete samples were prepared based on the composition in the table above, and their compressive strength and calculated thermal conductivity properties were studied. The results of the study are presented in Figure 2.

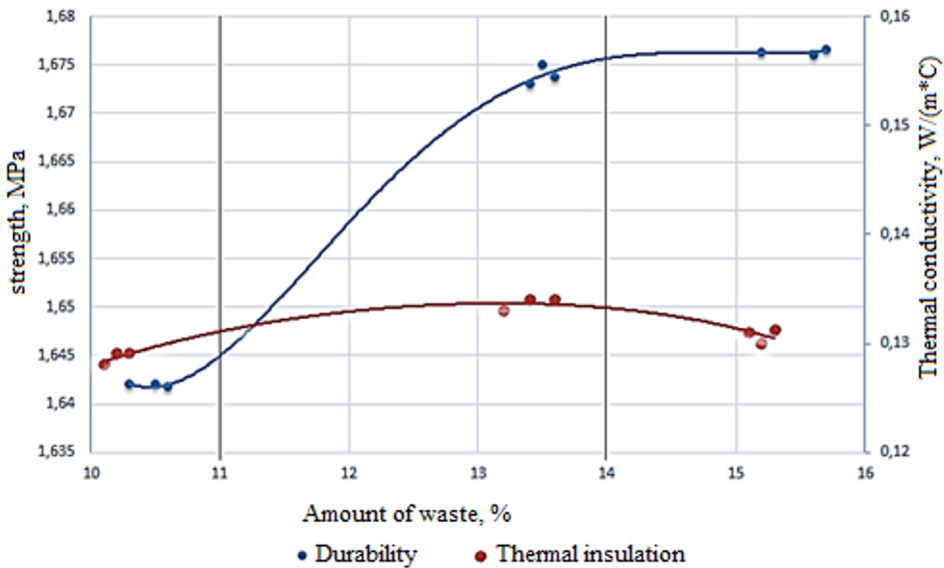


Fig. 3. Strength and thermal conductivity of aerated concrete with added industrial waste

According to the above graph, it was determined that the strength and heat-insulating properties of the composition with 5-6% slag and 8-9% waste quartz sand about the total amount of the mixture are high.

The obtained results showed that the developed composition fully complies with the normative indicators specified in the state standard as mentioned above (GOST-25485-2019 "Acellular concretes. Technical conditions"). In this case, the average density of aerated concrete blocks with added industrial waste was improved by 3-6%, thermal conductivity by 2-4.5%, and strength by 7-12%.

Using the mathematical method of planning the results of the experiment, industrial wastes included in aerated concrete: steel melting slag - X1; waste quartz sand - X2; The influence of aluminum powder - X3 on the average density ((ρ) g/cm³ (Y1)) and compressive strength ((Ps) (Y2)) of gas blocks was studied.

In this case, the equations obtained by the mathematical regression method have the following form:

– average density:

$$(Y1) - \rho = 0,637 - 0.128 X1 + 0.012 X1^2 + 0,013 X1X2 + 0.011 X1X3 + 0.032 X2 + 0.016X2^2 - 0.006 X2X3 - 0.008 X3 + 0.009 X3^2$$

– compressive strength:

$$(Y2) - R_s = 1.426 + 0.169 X1 - 0.034 X1^2 - 0.131 X1X2 - 0.021 X1X3 + 0.134X2 + 0.041 X2^2 - 0.026 X2X3 - 0.033 X3 + 0.036 X3^2.$$

The analysis of these equations shows that steel melting slag - X1 can be cited as the main influencing factor on the strength and average density of aerated concrete. The combined effect of steel smelting slag and waste quartz sand is next - X1X2. In this equation, it was noted that aluminum powder - X3 has a small effect. The level of reliability of the above mathematical regression equations was $R^2=0.82-0.87$.

At the next stage, automated calculation programs for designing the composition of aerated concrete blocks and determining the amount of added industrial waste were developed to produce D600-D900 aerated concrete blocks.

The experiment results show that 0.1-0.3 mm pores were 10-12% in the composition obtained from production and 20-24% in the samples with added industrial waste. The increase in the number of micropores when the samples are compared is because the surfactants in the steel smelting slag facilitate the hydration reaction in the mixture.

4 Conclusions

1. Research and experiments were conducted to determine the composition of aerated concrete without autoclave from industrial waste raw materials. The number of necessary compositions for the aerated concrete mixture was calculated. As a result of the experiments, the role of the effects on their physico-mechanical and chemical properties was studied using industrial waste products for aerated concrete without an autoclave.

2. Based on the experimental-statistical models of the aerated concrete composition, it was determined which component strongly influences the composition, and the analysis was carried out. Empirical formulas for density, strength, and moisture were created, and effect graphs were constructed. As a result, to ensure the necessary physical and mechanical properties, research determined that the content of steel melting slag in aerated concrete should be in the range of 11-13 percent and quartz sand in the range of 14-16 percent.

3. Based on the analysis of the obtained results, in determining the properties of aerated concrete using standard methods, a composition corresponding to the normative indicators specified in the state standard GOST-25485 was developed; its frost resistance level is F25, the average density is 3-6 percent, thermal conductivity is 2-4.5 percent, 7-12 percent improvement in strength was achieved.

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