Development of Production Technology for Artificial Porous Gravel of Stone-Like Clay

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Abstract - *This article is dedicated to the production of high quality expanded clay based on low-emitting stone-like hydromicas clay. The developed technology makes it possible to expand the raw material base of aggregates for lightweight concrete and improve their physical and mechanical properties. The researches revealed that there are not enough gas-forming substances in stone-like clay composition, which are the main factor of the formed porous formation during blowing. Therefore, the influence of various porous admixtures on the swellability of this clay was studied. At the same time, researches were carried out on the bloating of stone-like low-emitting clay depending on the bloating regimes. It is revealed that the clay swellability and physico-mechanical properties of the obtained aggregate depend on the temperature of pre-treatment, temperature and duration of swellings.*

Keywords -- *clay, swelling, temperature, density, strength, expended clay, lightweight concrete.*

INTRODUCTION

One of the main factors in increasing the efficiency of construction is the reduced mass of building structures without loss of their bearing capacity and other operational properties. The use of lightweight concrete in 1.5-2.5 times reduces material costs compared to conventional heavy concrete of the same class in terms of strength [2, 3, 4, 5].

One of the most effective ways to solve these problems is the production and use of lightweight concrete products and structures on artificial porous aggregates [1, 2, 5].

New lightweight aggregate such as expanded clay with high mechanical and physical properties is required to produce highly efficient lightweight concrete.

Recently, the most enterprises producing expanded clay are based on low-quality raw materials due to the lack of blowing clay. Incorporating various remedial admixtures into the charge leads to the improvement of clay materials' swellability [6, 7, 8, 9, 13].

There is no well swelling clay raw material in the territory of the Republic of Azerbaijan. Simultaneously, there are huge natural reserves of low-emitting stone-like clay in Sumgaitchay deposit. It is impossible to process them with the existing methods and to get claydite gravel with improved physical and mechanical properties.

Therefore, the development of scientific bases and technology for the production of lighweight and high-strength porous aggregates for thermal insulation, insulating structural and structural lightweight concretes from low-emitting stone-like clays of Sumgaitchai deposit is an actual and important task of the industry of artificial porous aggregates.

The objective of these researches is to identify the possibility of obtaining and establishing the basic regularities aimed at controlling the porous structure and phase composition of aggregates based on low-emitting stone-like clay, as well as the technology development for the production of porous aggregates with specified physical and mechanical properties [10].

EXPERIMENTS PERFORMANCE

When conducting the experimental studies and industrial inspections, the stone-like low-emitting hydromicas clay of Sumgaitchai deposit was used, the chemical composition of which is presented in Table 1.

Experimental studies were conducted in three stages: at the first stage of charge preparation and production of raw granules, at the second stage the study of mass swelling kinetics and aggregate structure formation, at the third stage the study of petrography and physico-mechanical properties of the produced artificial porous aggregate. X-ray, differential thermal and petrographic analyses were used during the experimental studies.

TABLE 1
CHEMICAL COMPOSITION OF CLAY OF THE SUMGAITCHAY DEPOSIT

Name of raw materials	Oxides, %								
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O+ K_2O	SO_3	Calcination losses	Σ
Stone-like clay of the Sumgaitchay deposit	57,58	18,68	7,59	0,42	3,97	4,92	0,29	6,55	100,00

Industrial tests and clarification of technological parameters of porous gravel production were carried out at the technological line for the production of light aggregates in Sumgayit city.

MATERIALS

Brown-red clay consists mainly of hydromicas, which also contains kaolinite, montmorillonite, chlorite, quartz, feldspar, gypsum, calcium carbonate. The content of hydromicas in it is 66-70%, which gives grounds to classify it as hydromicas clay. The clay is dense, stone-like, and hard to soak, medium-plastic, the number of plasticity is 17-23, the sintering temperature is 10000C. Its granulometric composition is characterized by homogeneity; the clay fraction is 70-85%. According to the swelling coefficient (K=1.15), it is located between the low-emitting and non-emitting clays.

SPECIMENS

In the researches on the study of mass swelling kinetics based on Sumgayitchay clay samples from specially prepared charge were produced with the use of correcting admixtures in the form of cylinders with the diameter and height of 16 mm, as well as granules on a laboratory plate granulator with the size of fractions 5-10 mm. To study the processes of structural formation during the heating of blowing masses and the formation of a porous structure we applied methods of microscopic and petrographic analysis.

ANALYTICAL STUDY

Structural changes in stone-like clay occur after the temperature of 100 degrees, before 100 degrees there is a drying process and no other changesare observed.

As we can see from Figure 1, in the range of 100-700^{0}C there is an expansion, which is 0.6-0.7% of the volume. Further, at influence of temperature above 750^{0}C the shrinkage occurs and formation of a liquid phase begins. Maximum shrinkage is fixed at 1000^{0}C, during this period to ensure swelling and formation of porous structure in granules it is necessary to form gas-like phase. There are not enough gaseous substances in the chemical composition of this clay, so the process of swelling does not take place during heating, which requires an artificial insertion of a gas-forming agent into the masses of the clay, and this is the main task of the swelling process of granules made of stone-like low-emitting clay. For this purpose, it is necessary to dry and remove the physically bound water from the

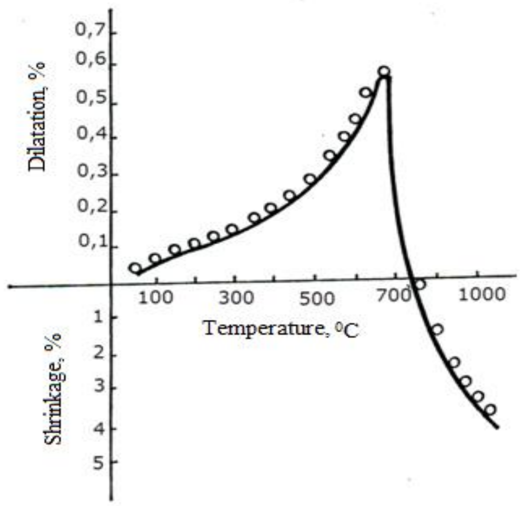

Fig. 1. Structural changes of the Sumgaitchay stone-like clay depending on reheat temperature

composition, to destroy the primary structure of stone-like clay, to insert gas-forming admixtures into the composition and jointly disperse the clay with admixtures. Then it is necessary to granulate the powder mass and get raw granules. Liquid admixtures can be added at receiving of raw granules from a powder.

Co-grinding ensures that the entire volume of the gas-forming unit is evenly distributed, which results in a homogeneous porous structure that is evenly distributed throughout the entire volume of the granule when swelling [11].

Primary porous structure is formed during powder granulation, the remaining pores are fixed by swelling.

After drying, the porosity of raw granules is 30-31%. Results of researches are presented in figures 2 and 3.

The study of swelling kinetics of samples produced from low-emitting stone-like hydromicas clay showed that as the temperature of swelling rises from 10,000C to 11,000C in samples without additives, no formation of porosity occurs.

Porosity does not change and is 30-31%. With an increase in the swelling temperature above 11000C, an insignificant amount of gases is released from the clay composition (Fig. 2, curve 1), the formation of a porous structure and expansion of the sample volume begins.

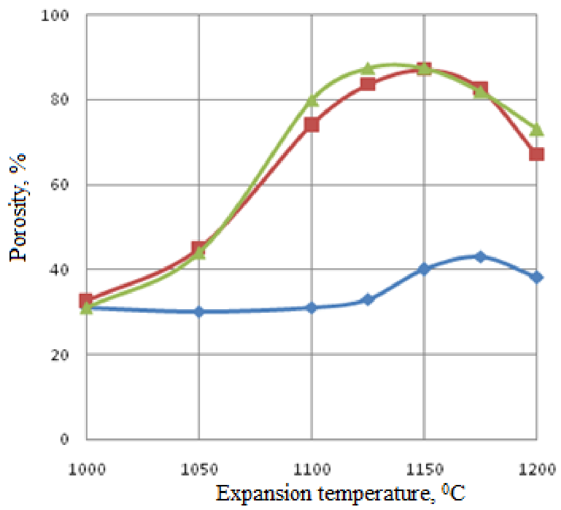

Fig.2. The change in porosity of the expanded specimens made from the Sumgaitchay clay depending on expansion temperature

1 - without additives
2 - with addition of 3% of used gumbrine
3 - with addition of 1% of alkaline waste

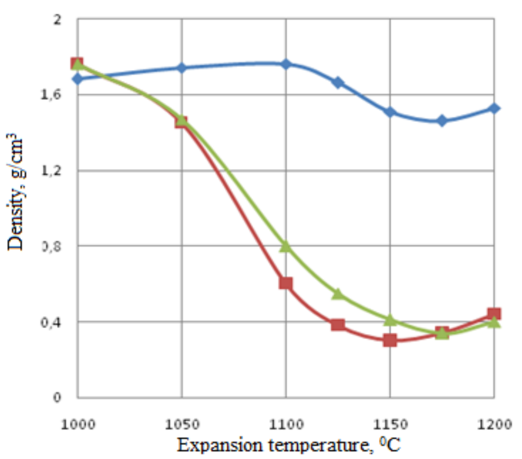

Fig.3. The change in density of the expanded specimens made from the Sumgaitchay clay depending on expansion temperature

1 - without additives
2 - with addition of 3% of used gumbrine
3 - with addition of 1% of alkaline waste

At 1125ºC the porosity increases and makes 34-35%. The density is 1.62 g/cm^3 (Fig.3, curve 1). At the further increase of temperature up to 1170ºC increase in porosity of samples is noticed. Maximum swelling is fixed. Thus, porosity comprises 44% (Fig.2, curve 1), with the increase of porosity the density reduction begins. The density of the swelled samples decreases only to 1.44 g/cm^3 (Fig.3, curve 1). The increase in the swelling temperature up to 1200ºC on the surface of the samples, there is a melting and reduction of samples' porosity observed. The porosity of samples decreases to 35-38%.

To increase the swellability of this clay, gas-forming admixtures were used. The results of researches have shown that with addition of 3% of developed humbrine, or 1,0% of alkaline waste (Fig.2, curves 2 and 3), the character of porosity curves changes sharply. Intensive porosity formation begins at 1025-1030°C. At further increase of swelling temperature up to 1150°C formation of porous structure continues. Porosity of blown samples is reached up to 85%. With the increase of porosity there is a decrease in the density of the blown samples and reaches its maximum. The density is reduced to 0,32-0,34 g/cm^3 (Fig.3, curves 2 and 3).

The study results have demonstrated that to provide formation of porous structure through the whole volume of granules and to avoid cracking as well as to enhance thermal resistance of raw granules they must be preliminary heat up to the temperature below the beginning of burn-up of gas-forming additions [12].

The results of research on the influence of the temperature of preliminary thermal preparation on the swellability of Sumgayitchay stone-like clay are shown in Fig. 4.

Figure 4 shows that the temperature of preliminary thermal preparation of the mass basing on Sumgayitchay stone-like clay in the range from 250-300°C allows to get aggregate with the density of 0,32-0,34 g/cm^3.

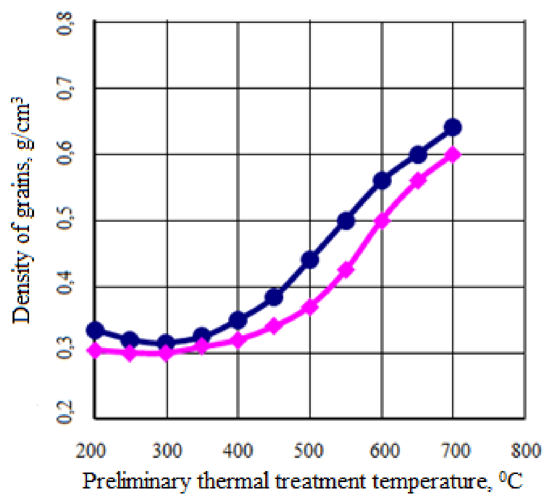

Fig. 4. The influence of a preliminary thermal treatment temperature on the density of the specimens made from masses based on the Sumgaitchay clay with additives

1 - alkaline waste 1%
2 - used gumbrine 3%

An increase in a preliminary thermal treatment temperature up to 400-500^{0}C leads to a rise in density of the expanded granules from 0.32g/cm^3 to 0.37-0.45g/cm^3 and with increase in a preliminary thermal treatment temperature up to 600-700^{0}Cthe nature of the curves changes noticeably and the density of expanded granules goes up to 0.60-0.64 g/cm^3.

The microscope studies of the aggregate point to the fact that an increase in a preliminary thermal treatment temperature over 400^{0}C simultaneously with a rise in density of the granules results in an increase of the number of crushed grains of coarse fraction.

Studies of the effect of swelling duration on the formation of porous structure shows that in granules with or without admixtures, sintering and deformation occurs within 3-4 minutes, and the beginning of gas release is marked after the specified time. Swelling of granules produced with the use of 3.0% of used humbrinis completed within 6-7 minutes.

Intensive porosity of granules starts after the fourth minute of their entering the burning zone. The formation of a porous structure lasts up to 6 minutes. As the duration of swelling increases to 8 minutes, the density does not change. This indicates that the gas separation has been completed and the pore size does not expand. With further increase of swelling duration in the burning zone up to 10-12 minutes the increase of density of swelled granules and change of pore shape on the surface layer is noted. Optimal porous structure is formed with the burning duration of about 6-7 minutes.

Structural elements are represented by fine-grained glass substance permeated with amorphized dark grey material. The latter, in terms of their high index of light refraction, differ from the main glassy mass. The pores have different shapes, mostly irregularly spherical, with diameters ranging from 5-8 microns up to 0.3 mm.

The content of pores reaches 68-70%. Microstructure of the aggregate produced from Sumgaitchay clay is shown in Figure 5.

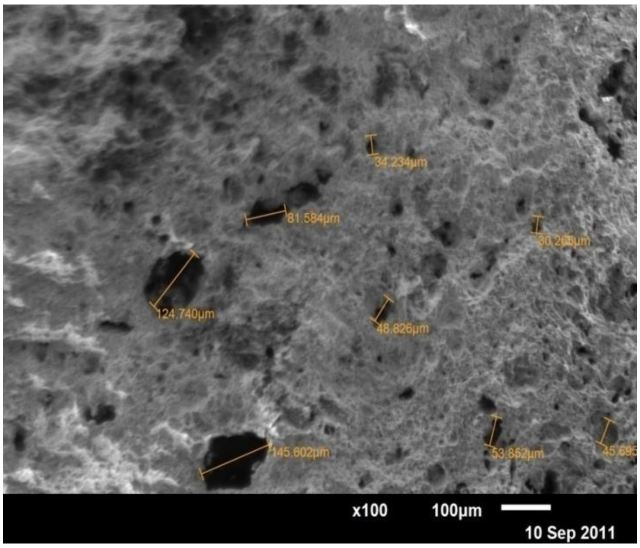

Fig.5. Microstructure of porous gravel based on the Sumgaitchay clay

Thus, the results of research show that the following technological operations are necessary for the use of stone-like hydromicas low-emitted clay as the main raw material: to destroy the primary natural structure of the clay, remove physically bound water from the clay composition, insert the optimal amount of gas-forming admixtures into the masses, make raw granules and blow them up in the optimal mode of swelling.

The study results were integrated into the light aggregates production line in Sumgait city.

The physical and mechanical properties of light aggregate expanded at the plant's production line are shown in Table 2.

TABLE 2

PHYSICAL AND MECHANICAL PROPERTIES OF LIGHTAGGREGATEPRODUCED FROM STONE-LIKE LOW-EMITTED CLAY (INDUSTRIAL TEST)

Nos	Aggregate characteristics	Aggregate brand by bulk density			
		300	400	500	600
1	Density, g/cm^3	2,46	2,46	2,48	2,48
2	Bulk density, kg/cm^3	270-300	380-400	420-480	570-600
3	Compression strength in cylinder, MPa	1,0-1,4	1,7-2,2	2,3-2,8	3,5-4,0
4	Average value of gravel grain shape coefficient	1,1	1,0	1,0	1,0
5	Contents of fractured grains in gravel, % by weight	6-8	4-5	5-7	4-6

The results of industrial research show that the physical and mechanical properties of light aggregates obtained from stone-like hydromicas low-emitted clays meet the requirements of current standards [14]. They are recommended as a coarse aggregate for the production of lightweight concrete, as well as thermal and soundproofing fillings.

With the use of the obtained aggregates, optimum compositions of lightweight concrete were selected. Dense sand was taken as a fine aggregate.

Results on the selection of lightweight concrete composition and their physical and mechanical properties are provided in Table 3.

Using porous gravel of density brand 300-700, dense sand and plasticizing additions, lightweight concrete of 1750-1780kg/m^3 in density and strength of 36.5-42.5MPa has been produced. And by using porous gravel, dense sand without plasticizing additions lightweight concrete with density of 1250-1800kg/m^3 and strength of 10.2-29.7MPa has been obtained.

TABLE 3.
COMPOSITIONS AND PHYSICOMECHANICAL PROPERTIES OF LIGHTWEIGHT CONCRETES MANUFACTURED FROM POROUS GRAVEL ACCORDING TO THE DEVELOPED TECHNOLOGY OF STONE-LIKE CLAY

Nos.	Consumption of materials for1m^3 of concrete, kg						W/C	Plasticity of concrete mix	Density of concretes, kg/m^3		Ultimate compression strength, MPa	
	Aggregate of fraction, mm			Cement	Pleasticizing addition, SK-18 1.0-1.5% of cement mass	Water, l			Freshly laid concrete	Dry concrete	after steam treatment	at the age of 28 days
	10-20	5-10	0-5									
1	285	195	478	254	-	210	0,82	1-3	1406	1250	7,35	10,2
2	260	263	520	310	-	211	0,68	1-3	1564	1400	11,83	16,8
3	200	217	770	385	-	235	0,61	1-3	1807	1630	14,5	19,8
4	187	200	880	420	-	244	0,58	1-3	1930	1750	19,2	26,3
5	170	210	890	460	-	235	0,51	1-3	1965	1800	21,6	29,7
6	50	250	890	480	6	206	0,43	1-3	1882	1750	25,5	36,5
7	30	230	880	550	7	225	0,41	1-3	1922	1780	29,7	42,5

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