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Study of the Processes in Swelling of Expanded Clay Masses Based on Raw Materials of Uzbekistan

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ABSTRACT: The article investigates the possibilities of obtaining high–quality expanded clay based on the clay of the Gurlen deposit of the Republic of Uzbekistan, with additives from local oil and fat combines – gossypol pitch and local dune sand of Tuprakkala massif. It is determined that the addition of gossypol pitch to the raw mixture within the specified limits significantly increases the swelling of the mass. It was also determined that the addition of dune sand to the mass (together with gossypol pitch) in moderate quantities contributes to an increase in mechanical strength and lengthening of the swelling interval of experimental expanded clay samples.

KEYWORDS: clay, expanded clay, gossypol pitch, porous aggregate, roasting, sand dune, swelling, organic and mineral additive, thermal insulation material.

INTRODUCTION

Expanded clay is a porous material obtained by firing clay or clay shale, etc. Due to the unique heat and sound insulation properties, this material has been used in many areas of construction [1].

Fundamental research on the technology of producing expanded clay was carried out by S.P. Onatsky. In his works [2, 3], he considered the theory and practice of the production of expanded clay. The physicochemical and technological bases of obtaining materials such as expanded clay, a variety of raw materials and additives, including clay, shungites, siliceous shales and other rocks, are covered in detail.

Usually, low–melting clay rocks are used for the production of expanded clay, which have a tendency to swell during rapid firing. The chemical composition of such clays is usually characterized by the following content of oxides (in %): SiO_2–50–65, Al_2O_3 –10–25, Fe_2O_3+FeO–3, 5–4,0, CaO+MgO up to 7, R_2O–3,5–5, the content of fine organic impurities from 1 to 2 and free silica up to 25 [4].

As is known, various additives are used in the production of expanded clay to increase the strength of expanded clay and the swelling capacity of clay and to expand its temperature range of swelling, etc.

According to the physical state, additives are divided into solid and liquid. As liquid additives, salt oil, fuel oil, petrolatum, anthracene, pyrolysis pitch, shale oil and sulfide–alcohol bard are used, and as inorganic solids – pyrite and pyrite cinders, and organic – ground coal, sawdust, humbrin, etc. [5].

Organic additives are usually added when the content of natural organic impurities in clay is less than 1–2%. The total content of organic impurities and additives should not exceed 2% [2].

The pyro plastic state in expanded clay occurs as a result of the accumulation of a sufficient amount of liquid phase in it – silicate melt. The intensity of the accumulation of the liquid phase depends primarily on the chemical composition of the clay and additives. It increases with an increase in the alkali content in clay and decreases sharply as free quartz increases in it [6].

The studies conducted by N.E. Toporkova and V.A. Kutugin [7] show that clays containing more than 65% SiO_2 are in most cases unsuitable for the production of expanded clay. As the content of SiO_2 increases and the content of $A1_2O_3$, Fe_2O_3, MgO, Na_2O and K_2O decreases the swelling of clay rocks decreases. A large amount of quartz in clay rocks, especially in large grains, worsens the swelling of clays. Meanwhile, he noted that the presence of 10–12% finely dispersed quartz in clay rocks does not significantly affect the swelling of clays during firing.

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However, in the works [8–11], scientists of Kazakhstan developed a resource–saving technology of granular porous thermal insulation material of the “expanded clay” type based on loess–like loam modified with a conglomerate mixture consisting of oil sludge and dune sand. It is established that the introduction of a certain amount of fine–grained dune sand creates a reinforcing matrix in the structure of a porous aggregate and contributes to an increase in the strength characteristics of the finished product.

The above data show that the available statements about the decrease in the strength characteristics of expanded clay in the presence of free quartz are reliable only with its increased content in the mass. We [12] also proved the positive effect of the addition of free quartz to the expanded clay mass in a homogeneously distributed state, under certain conditions, on the physico–mechanical properties of expanded clay.

Thus, by direct action on the structure, taking into account the properties of clay and other raw materials, it is possible to obtain expanded clay materials with improved physical and mechanical properties.

MATERIAL AND METHODS

One of the varieties of fusible clays of the Republic of Uzbekistan is the clay of the Gurlen deposit located in the Tuprakkala district of the Khorezm region [13].

We [14] found that the moderate chemical and mineralogical composition, fine dispersion and a small amount of finely dispersed free quartz, give fusibility and swelling to Gurlen clay during rapid firing and allow it to be used in the production of expanded clay.

In this regard, the purpose of this work is to study the influence of clay from the Gurlen deposit together with local promising additives on the swelling processes and properties of expanded clay aggregate.

When developing the compositions of experimental expanded clay masses, promising local components were used as an additive, such as dune sand of the Tuprakkala massif and gossypol pitch.

It should be noted that, in the composition of the projected masses, the additive gossypol pitch is used as an organic additive to increase the swelling of clay. Tuprakkala dune sand in the composition of the projected masses is used to increase the strength of expanded clay and to expand its temperature range of swelling in a homogeneously distributed state.

To obtain expanded clay in the laboratory, the standard method according to GOST 32026–2012 was used “Clay raw materials for manufacturing of clayite gravel, rubble and sand. Specifications”.

The physical and mechanical properties of the fired samples were determined according to GOST 9758-2012. “Non–organic porous aggregates for construction work. Test methods”.

RESULTS AND DISCUSSION

In order to study the influence of the raw materials used on the processes of swelling of expanded clay materials during firing, prototypes were molded using a plastic method from the selected masses presented in Table 1. The molded samples were dried under natural conditions and to remove interpacket water in an oven at a temperature of 170–180^{o}C to constant weight and subjected to appropriate heat treatment.

Then the heat–treated prototypes were fired at various temperatures, starting from 900^{o}C to 1110^{o}C with an interval of 30^{o}C and with exposure at the final temperature for 7 minutes.

Table 1. Charge compositions of experimental expanded clay masses

Mass indices	Content of components, mass %		
	Gurlen clay	Gossypol pitch	Tuprakkala dune sand
M–1	100	–	–
M–2	99	1	–
M–3	98	2	–
M–4	97	3	–
M–5	96	2	2

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M–6	94	2	4
M–7	92	2	6
M–8	90	2	8
M–9	88	2	10

Studies of the processes of swelling of experimental expanded clay masses were carried out by determining the physical and mechanical properties at different firing temperatures. The dependences of the physico–mechanical properties of the experimental expanded clay masses on the firing temperature are shown in Fig.1–3.

At a firing temperature of 1020-1050°C, with an increase in the content of added gossypol pitch in the mass of the experimental samples M–2, M–3 and M–4, a decrease in bulk density is observed, for the masses M–2 and M–3, this indicator is 460 kg/m^3 and 350 kg/m^3, respectively. In the mass of M–4, with an increase in the amount of gossypol pitch up to 3%, there is a slight decrease in the bulk density content up to 330 kg/m^3 (Fig.4). The swelling coefficient at 1050°C for the masses of M–2, M–3 and M–4 is 4,02, 4,75 and 4,82, respectively (Fig.4).

In addition, the mechanical strength and swelling interval of samples of mass M–4 is reduced to 0,6 MPa (Fig.4) and 40°C, respectively. It should be noted that the mechanical strength of the samples from the M–4 mass does not meet the requirements of GOST 9757–90.

Based on this, the maximum content of gossypol pitch added as an organic is 2 %.

In order to increase the mechanical strength of the samples and to lengthen the swelling interval of the masses, dune sand of the Tuprakkala massif was also added to the experimental masses in an amount of 2–10%.

It can be seen from Fig.5 that in the experimental masses M–5, M–6 and M–7 at 1050°C, with an increase in the content of dune sand, the bulk density first slightly increases and the swelling coefficient decreases slightly, the mechanical strength of the samples increases intensively. In the experimental masses M–8 and M–9, with a further increase in the content of sand dune, a slight increase in the bulk density index and a decrease in the swelling coefficient continues, and the intensity of the increase in the mechanical strength of the samples weakens. For experimental masses M–7, the swelling interval is 80°C, and for masses M–9, this indicator is reduced to 60°C.

From Fig.1 and Fig.3 it can be seen that starting from 1000°C, the properties of the experimental masses undergo noticeable changes. In the temperature range of 990-1020°C for the masses of M–3 and M–7, an intensive increase in the swelling coefficient is observed, as well as an intensive decrease in the bulk density and mechanical strength of the samples.

The bulk density of samples at 1000°C for the mass of M–3 and for the mass of M–7 is 600 kg/m^3. The bulk density at 1020°C for the mass of M–3 decreases to 350 kg/m^3, and for the mass of M–7 at a temperature of 1020°C is 380 kg/m^3. Further up to 1050°C, the bulk density for the mass of M–3 remains unchanged, which means the interval of the baked state of the mass. And for the masses of M–7, this temperature rises to 1080°C.

In this temperature range, the mechanical strength of samples from the mass M–3 (1020–1050°C) remains unchanged 1,3 MPa, and the strength of samples from the mass M–7 (1020–1080°C) increases from 2,0 MPa to 2,2 MPa. At 1080°C, the mechanical strength of samples from the M–3 mass increases to 1,4 MPa. At the same time, the swelling coefficient for the mass of M–7 is – 4,55 (Fig.4 and Fig.5).

Thus, with an increase in temperature from 1020 to 1050°C for the mass of M–3, and from 1020 to 1080°C for the mass of M–7, the curves of the dependence of bulk density, the swelling coefficient and mechanical strength smoothly turn into a horizontal line, which indicates that the maximum values are achieved during the process of swelling of the material.

Water absorption of swollen samples of the studied masses < 20%. For the mass of M–3 at 1080°C, the bulk density and mechanical strength increase to 410 kg/m^3 and 1,4 MPa. For the mass of M–7 at 1110°C, the bulk density and mechanical strength increase to 400 kg/m^3 and 2,4 MPa (Fig.1 and Fig.2).

With a further increase in the firing temperature of samples for M–3 to 1080°C and for M–7 to 1110°C, an increase in bulk density to 410 kg/m^3 and 400 kg/m^3 is observed, respectively, the swelling coefficient decreases markedly – to 4,41 and 4,49, respectively. There are signs of melting in the samples, an increase in the density of the samples begins, deformation elements begin to appear, which is contrary to the process of swelling.

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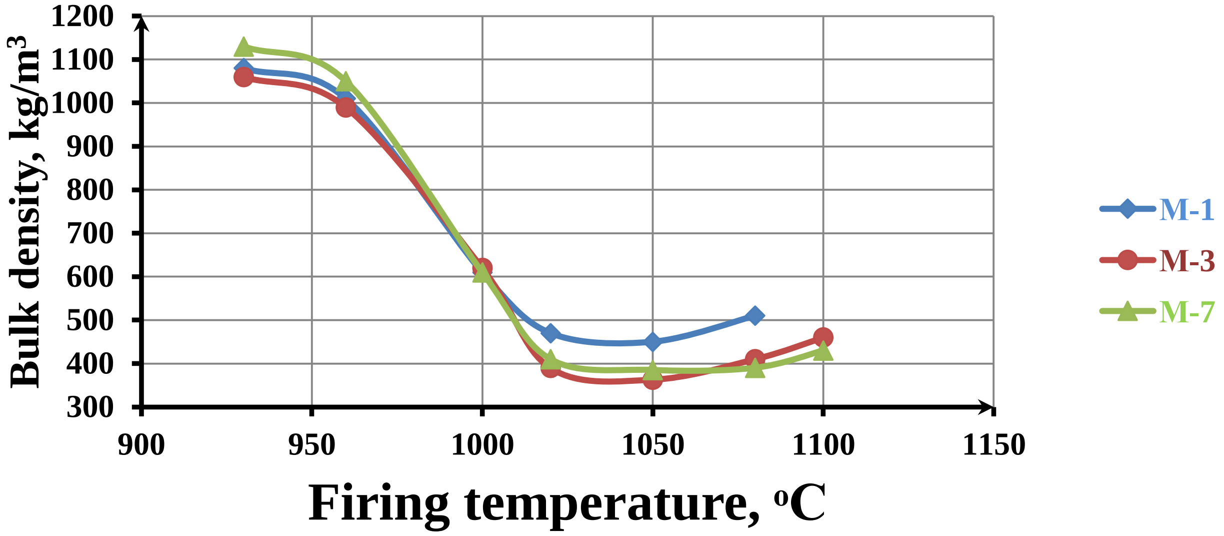

Fig.1. Dependences of the bulk density of expanded clay masses on the firing temperature

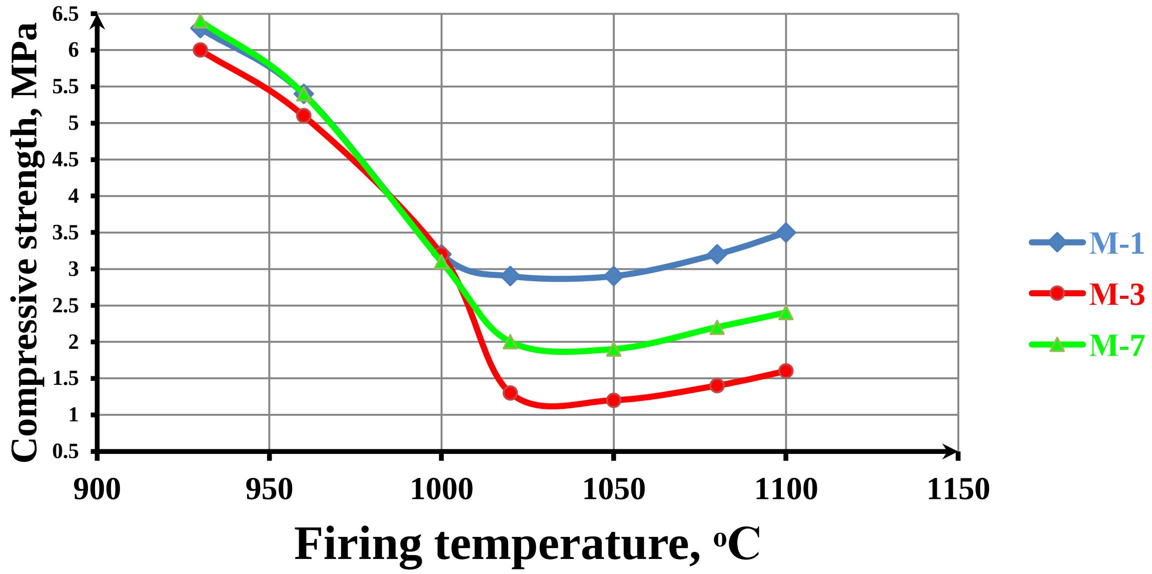

Fig.2. Dependences of the mechanical strength of expanded clay masses on the firing temperature

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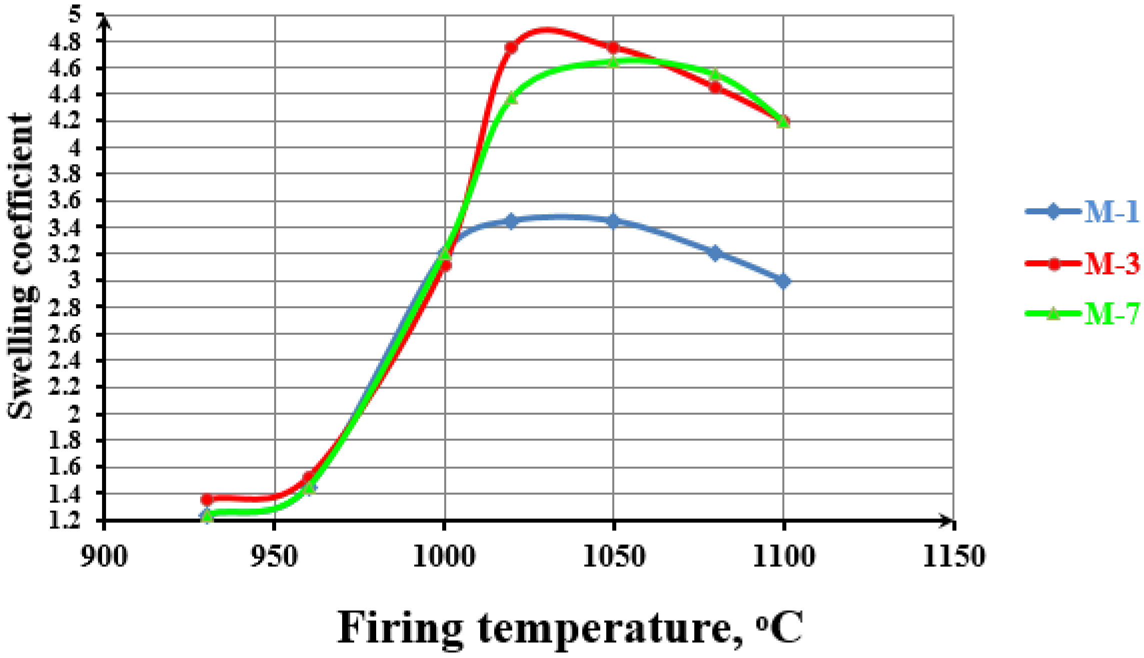

Fig.3. Dependences of the swelling coefficient of expanded clay masses on the firing temperature

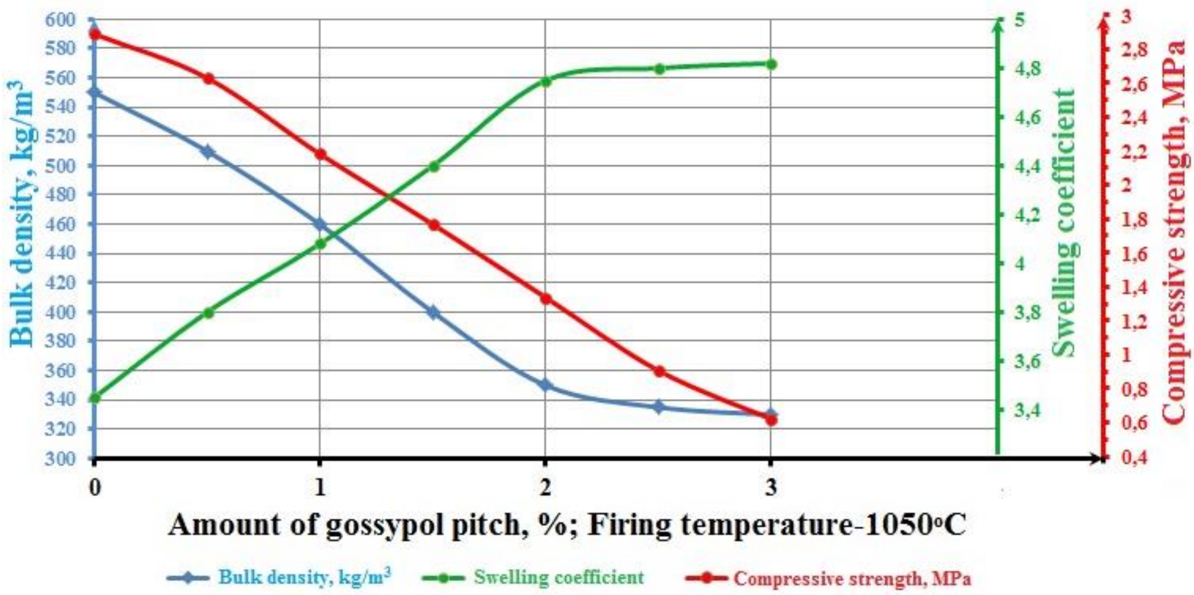

Fig.4. Dependences of physical and mechanical properties of expanded clay masses on the content of gossypol pitch

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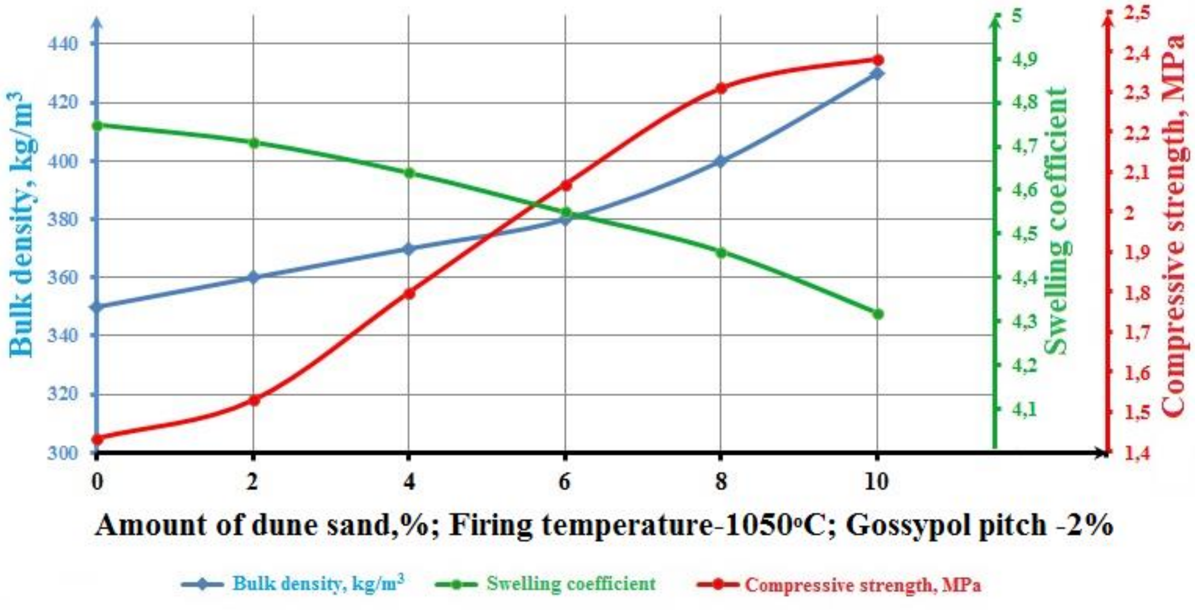

Fig.5. Dependences of physical and mechanical properties of expanded clay masses on the content of dune sands

Based on the above studies, the following conclusions can be drawn:

The correcting organic additive - gossypol pitch, in an optimal amount of 2%, has a noticeable effect on the swelling processes and helps to reduce the bulk density of the experimental masses at the optimal firing temperature.

The corrective mineral additive Tuprakkala dune sand in optimal quantities has a beneficial effect on the structure formation of the porous aggregate and leads to an increase in strength and lengthening of the swelling interval of the experimental masses.

Thus, based on the conducted research, it was found that the complex use of Gurlen clay and promising local corrective additives in the composition of expanded clay masses contributes to the production of expanded clay materials with improved physical and mechanical properties at relatively low firing temperatures of 1020–1080°C.

At the same time, it should be noted that, in the optimal mass of M–7, complexly using additives of gossypol pitch and dune sand, a light and sufficiently durable expanded clay material with a bulk density of 380 kg/m^3 was obtained, belonging to the group of well–swelling (4,55) with a wide swelling interval (80°C), compared with expanded clay material obtained from pure Gurlen clay (M–1) with a bulk density of 550 kg/m^3, belonging to the group of medium swelling (3,45), with an average swelling interval (50°C).

CONCLUSION

As a result of the research, effective compositions of expanded clay masses based on the Gurlen clay of Uzbekistan have been developed using available local corrective additives, such as gossypol pitch and Tuprakkala dune sand. For the first time, the use of gossypol pitch as an organic corrective additive in the production of expanded clay was established.

It is also established, that the Tuprakkala dune sand in optimal quantities during the firing process plays a reinforcing role of the matrix in the structure of the porous aggregate leads to an increase in strength and lengthening of the swelling interval of the experimental masses.

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