Improving the thermal properties of lightweight concrete exterior walls

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Abstract. This article is devoted to the development of energy-efficient porous expanded clay concrete for exterior walls. Experimental data confirming the expediency of designing the optimal composition of porous concrete according to the general method of designing the optimal composition of the general theory of artificial building conglomerates (ABC) are presented. The presence of waste ash from thermal power engineering and a complex gas–forming agent based on the polymer K-9 reagent in the concrete provided increased durability, improved humidity and thermal engineering conditions of porous concrete.

1 Introduction

Increasing the requirements for the level of thermal protection of building enclosing structures in a dry, hot climate contributes to the intensive development and introduction into practice of construction production of effective enclosing structures with relatively low thermal conductivity coefficients and low water absorption. In the seismically active regions of Uzbekistan, in the production of external enclosing structures of buildings, as is known, it is necessary to use lightweight concrete, which must have a fused structure that provides sufficient protection from atmospheric moisture at high thermal protection indicators, and reinforcement from corrosion.

On the basis of a complex gas-forming agent, a porous expanded clay concrete was obtained, which is characterized by a decrease in average density by 100-150 kg/m^3. Replacing a part of expanded clay sand in expanded clay concrete with ash (50% of the volume and a complete 100% replacement) having an amorphous structure and a bulk density lower than the bulk density of expanded clay sand leads to a decrease in thermal conductivity.

2 Method

When developing porous concrete according to the general method of designing the optimal composition of the general theory of artificial building conglomerates (ABC), initially (with specified materials and established technological changes: mixing, compaction, hardening

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mode, etc.), the activity (R*) of cement-ash stone of optimal structure is determined (Fig.1) [1-5].

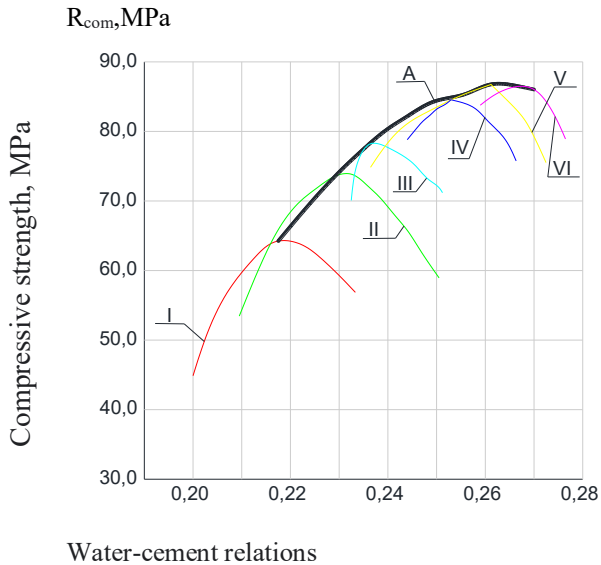

Fig. 1. Dependence of the compressive strength of cement stone on the water-cement ratio at different specific surface area of the Portland cement binder. Curve A is the envelope of cement binders of optimal structure; the curve with indices I, II, III, IV, V, VI correspond to the specific surface area (m^2/kg) of the Portland cement binder, respectively, at the time of its grinding 30', 45', 60', 90', 120', 180'. I - 280 m^2/kg; II – 320 m2/kg; III – 370 m^2/kg; IV – 400 m^2/kg; V – 450 m^2/kg; VI – 520 m^2/kg/. (note: digital data are taken from [3]).

Heat loss through lightweight concrete walls according to [1] is up to 30%. The problem of increasing the thermal properties of lightweight concrete exterior walls is combined with the problem of creating lightweight concrete.

Such concrete can be obtained in an effective way - by creating an optimally porous structure of the intergranular space, in other words, by porizing the binder.

At the same time, the porous expanded clay concrete makes it possible to make up for the absence of scarce expanded clay sand, reduce the density and thermal conductivity of concrete, reduce water demand and selling humidity of products, improve the connectivity and workability of the mixture and achieve a number of other advantages [2].

Porous expanded clay concrete with cement consumption equivalent to conventional expanded clay concrete has almost equal strength. The porous concrete mixture is less susceptible to water separation, since air bubbles seem to clog the channels through which water circulates. In this case, the intergranular space of expanded clay is filled with a porous cement paste consisting of small closed pores [3].

Aluminum powder, which is usually used for porization, has an undesirable ability to float on the surface of the water film, forming a scaly coating. In order to evenly distribute the pigment powder in the binder mass and dissolve the greasy film, additional substances are introduced. Therefore, it is much more expedient to use complex gas generators, which, being the initiators of gas evaporation, at the same time contribute to reducing the average density of concrete while maintaining its required strength with the lowest consumption of aluminum powder.

The authors have developed a complex gas-forming agent based on aluminum powder and polymer reagent K-9 (K-9 is a water-soluble multifunctional acrylate additive based on nitron fiber waste) in the amount of 0.002% by weight of the powder [4]. The K-9 additive, like all wetting additives of an ionic nature, envelops the particles of aluminum powder, evenly distributing them in the volume of the binder, preparing them for a joint spontaneous reaction.

For the design of compositions of porous expanded clay concrete of classes C 5 and C 7.5 based on cement-ash binder of optimal composition, the ash content in it is 25% and additives K-9 in the amount of 0.002% with a grinding time of -45 minutes. The highest activity value R* = 77.6 Mpa was obtained at C*/C =0.225.

The need to increase the binding activity was justified by the following reasons: R* is the calculated value included in the formula for the strength of conglomerates of optimal structure:

$$R_б = \frac{R*}{x^n}, \text{ where } x = \frac{\frac{W}{C}}{\frac{W*}{C}}$$

The amount of binder in the conglomerate depends on R*: the higher the R* value, the higher the W/C ratio the consumption of the binder decreases. In addition, according to the obligatory law of congruence, or the obligatory correspondence of properties, all strength, deformative and other qualitative indicators of a conglomerate are directly related to the same properties of a binder, and with optimal structures, their relationship is strictly natural. Therefore, it is necessary to have high-quality indicators of the properties of the binder and, in particular, strength.

To find the composition of porous concrete that meets the strength requirements R_{req}, it is first necessary to determine the permissible degree of porosity of the cement-ash stone using aluminum powder. Since the real activity of the binder R* is much greater than R_{req} of concrete, the cement stone can be porous to $R_{\_pores}$ *, and the degree of permissible porosity of the binder in the structure of lightweight concrete is found from the condition that ($R_{\_pores}$*) / $R_{\_req}$ = 2.0 - activity 3.5. Moreover, the higher the activity of the binder R*, the closer the degree of permissible porosity to 3.5

For the experimental determination of the required amount of aluminum powder for porosity of the binder, samples were made from cement-ash dough with different contents of aluminum powder at a given W/W ratio [1-27].

3 Technology

Aluminum powder was introduced into the binder in the form of an aqueous aluminum suspension. In water with a temperature of up to 800, the additive K-9 (0.002% of the powder weight) was dissolved, then aluminum powder (by weight) was poured into the solution and the suspension was stirred for 2 minutes.

After molding, holding, hardening according to the accepted regime and testing of samples, graphical dependencies are constructed – curves 1,2,3,4 in Fig.3. Curves 1,4 express the dependence of R of cement-ash stone (without K-9 additive) on the content of aluminum powder for concrete of classes B5 and B 7.5, respectively; curves 2,3 show the same dependence, but for cement–ash stone with a chemical additive K-9.

The data presented confirm the assumption that the K-9 additive is the initiator of gas emission. This is due to the fact that the aluminum powder PAK-3 used for porization has the ability to float on the surface of a water or oil film, forming a scaly coating.

The pop–up of pigment powders, which is a negative quality, is associated with the lamellar shape of the particles, the presence of fatty acid molecules on their surface and products of their interaction with the oxide surface of the metal - aluminum stearates. The K-9 additive, like all wetting additives of an ionic nature, envelops the particles of aluminum powder, evenly distributing them in the volume of the binder, prepares them for a joint spontaneous reaction [20-39].

That is, a kind of complex gas-forming agent is obtained, which provides a decrease in average density while maintaining Rtp / pores with the lowest consumption of aluminum powder. The effect of the K-9 additive on the gas-forming ability of aluminum powder was studied by the kinetics of gas release and swelling of cement-ash dough using the device in Fig. 2.

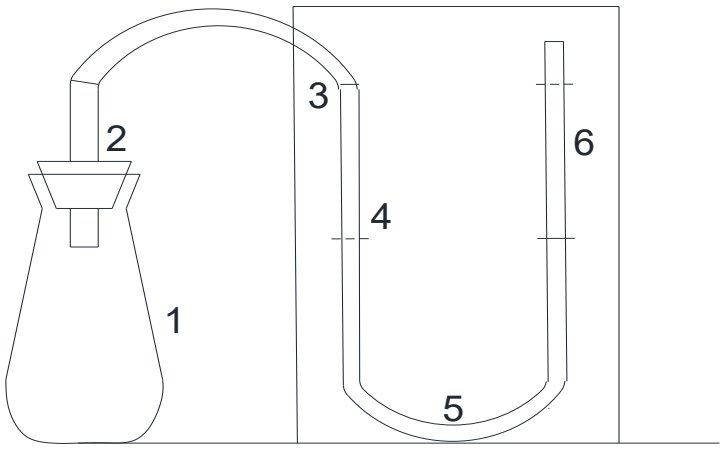

Fig. 2. Installation for determining the kinetics of swelling and gas release of cement stone 1 – glass vessel; 2- lid; 3 – exhaust pipe; 4 – graduated cylinder; 5 – connecting tube; 6 – equalization tube.

Fig. 3 shows the gas emission curves. The porized mixture had the same temperature - 40^0C, the rate of swelling and the time of gas release. The results show that the K-9 additive enhances the gas-forming ability of aluminum powder and allows it to be saved.

E R_{com},MPa

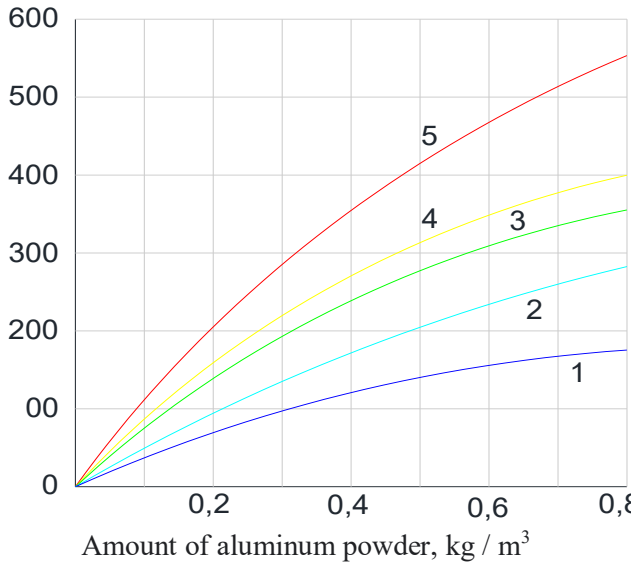

Fig. 3. Influence of K-9 additive on the gas-generating ability of aluminum powder. The numbers of the curves correspond to the content of the K-9 additive in the porous cement-ash dough: 1-0%; 2-0.0005%; 3-0.001%; 4 - 0.0015%; 5-0.002%.

4 Discussion of results

According to the research results, it has been established that to obtain a porous cement-ash binder for concrete of B5 classes (Rreq of concrete is 6.75 MPa) and for B 7.5 (Rreq of concrete is 9.0 MPa), the degree of permissible porosity can be taken equal to 3, 5, since R* = 77.6 MPa (there is a large difference between R* and Rreq of concrete). In this case, the activity of the porous binder is equal to Rtr / pore = 35.0 MPa [1-13].

It was determined that for the porosity of the binder containing the K-9 additive to obtain Rtr / pore = 35.0 MPa for class B5 concrete at a given average density of 900-1050 kg/m^3, it is necessary to introduce aluminum powder in an amount of 520-540 g/m^3 according to the indicated average density. To obtain a porous binder with K-9 for class B 7.5 concrete at a given average density of 1050-1100 kg / m^3, respectively, 500-400 g / m^3 of aluminum powder were required [5-22].

For the porosity of the binder without the addition of K-9, the consumption of aluminum powder was obtained for concrete of class B 5 and an average density of 900-1050 kg / m^3, respectively, 580-540 g / m^3, and for concrete of class B 7.5 and an average density of 1050-1100 kg / m^3, respectively 550-500 g / m^3.

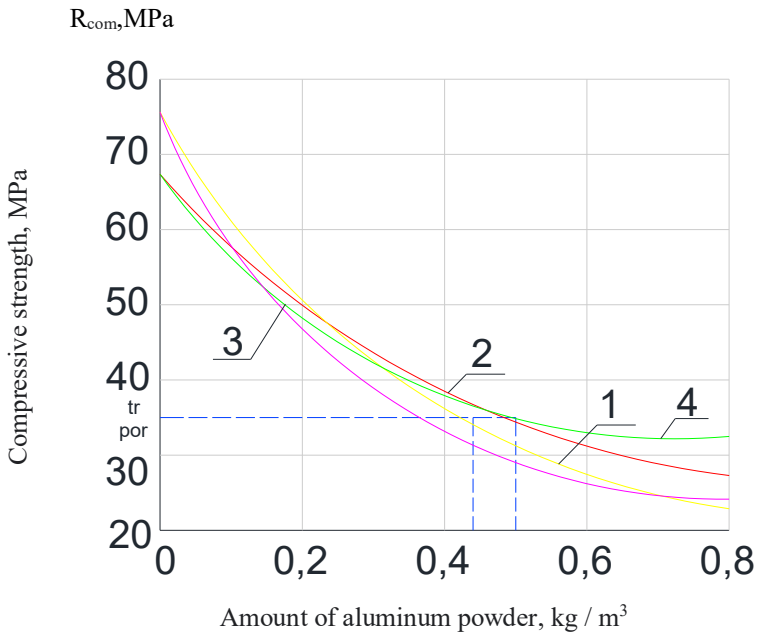

Fig. 4. Dependence of the strength of the porous binder on the amount of blowing agent. 1-cement-ash stone without K-9 additive (for concrete with an average density of 900-1050 kg/m^3); 2 - the same with 0.002% K-9; 3- cement-ash stone with 0.002% K-9 9 (for concrete with an average density of 1050-1100 kg / m^3); 4 - the same without K-9.

In the general case, in order to find the required content of aluminum powder at a given average density, it is necessary along the ordinate axis, as can be seen from Fig. 4, to postpone the value of Rtr / pore, translate it to the corresponding curve (1,2,3,4) and along the abscissa axis will find the required required content of aluminum powder in the cement-ash stone

5 Conclusion

On the basis of a complex gas-forming agent, a porous expanded clay concrete was obtained, which is characterized by a decrease in average density by 100-150 kg/m^3.

For the above types of lightweight concrete, the thermal conductivity depending on humidity was determined experimentally using the Block device using the method of stationary thermal regime. The combined use of ash, a multifunctional K-9 additive and a complex gas-forming additive reduces the thermal conductivity coefficient of porous concrete by 8.1% [6]. The thermal conductivity of concrete (class B5, B7, 5) at an average density of 900-1100 kg/ m^3 is in the range of 0.2-0.35 w/ m^3 (Fig. 2).

Mass loss in concrete was not noted.

The magnitude of shrinkage deformations of thermal insulation concrete on the developed complex gas generator is in the range (50-75).10-5 m.

A necessary indicator for forecasting and studying the thermophysical properties of concrete exterior walls during operation are the characteristics of mass transfer. The moisture characteristics of lightweight concrete are determined using a special moisture meter, which is based on the capacitive method based on the fact that cellular concretes as capillary-porous bodies are good dielectrics with a permittivity of 1-6. For water, this value is 8. According to the readings of the device, in accordance with the humidity

determination schedule, the fixed humidity value of the product is set. In the case of increased humidity values, its decrease should be corrected by reducing the initial moisture content of concrete and adopting a hardening regime in which two interrelated phenomena would be combined – heat and moisture hardening and drying of the material [14-28].

Thus, a porous expanded clay concrete for exterior walls has been developed, the optimal composition of which is determined by the general method of designing the optimal composition of the general theory of artificial building conglomerates (ABC). The use of waste ash from thermal power engineering and a complex gas-forming agent based on aluminum powder and polymer reagent K-9 in the composition of concrete made it possible to reduce the average density by 100-150 kg/m^3; the coefficient of thermal conductivity was reduced by 8.1%. In the outer walls of porous expanded clay-reinforced concrete, their humidity and thermal engineering modes have been improved, durability has been increased, fuel and energy resources have been saved, and sanitary and hygienic conditions in the premises have been improved [26-42].

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