 https://doi.org/10.1051/e3sconf/202340105043

Steam structure and thermal conductivity of lightweight concrete aggregate

M. A. Mirzajanov*, *M. M.* Ergashev, and *B. A.* Otakulov

Fergana polytechnic institute, Fergana, Uzbekistan

Abstract. The article describes the results of theoretical and experimental studies to identify the relationship between the parameters of the steam structure and thermal conductivity of ash-claydite. The correlation dependences of the thermal conductivity coefficient of ash-claydite on its parameters of the stream structure have been established. The analysis of these works shows that the thermal conductivity of lightweight concrete depends on the type of porous aggregate, on the direction of the heat flow in relation to the layering of the concrete, the average temperature at which heat transfer occurs, the average density and moisture content of the concrete. In most works, a significant effect of the steam structure of the aggregate on the thermal conductivity of concrete is noted.

1 Introduction

One of the main indicators characterizing the thermal properties of concrete is its thermal conductivity. The research of heat-conducting-news of light concrete is devoted to. numerous works of domestic and foreign scientists. Numerous works devoted to this problem have been published [1-8].

The analysis of these works shows that the thermal conductivity of light concrete depends on the type of porous aggregate, on the direction of the heat flow in relation to the layering of concrete, the average temperature at which heat transfer occurs, the average density and humidity of concrete. In most works, a significant influence of the pore structure of the aggregate on the thermal conductivity of concrete is noted.

However, there are no numerical data showing this dependence. In this regard, the purpose of this work is to study the relationship of the steam structure of a light filler with its thermal conductivity.

2 Methodology

*Corresponding author: mamirjonmirzajanov@gmail.com

The study was carried out on five series of ash-ceramsite obtained by us from bentonite clay of the Chita deposit of the Fergana region and ash-slag mixture of the Fergana thermal Power Plant (Uzbekistan) [9], the pore structure indicators of which are given in Table I.
As noted above, the thermal conductivity of light concrete largely depends on the thermal conductivity of the aggregate, since the latter occupies more than 80% of the volume of concrete. Therefore, in order to study the effect of the properties of a light aggregate on its thermal conductivity, it is necessary to have data on the thermal conductivity of the porous aggregate itself, it is difficult to test individual grains of the filler, and the thermal conductivity in the mound depends more on the intergranular voidness and the density of grain packing.

Table 1. Indicators of the structure of the pore space are gold-ceramsite

Zolokeramsite series		Total porosity P_{ob}, %	Parameters of the pore structure		
			Open porosity, P_{ot}, %	Conditionally closed porosity Puz, %	Average pore size indicator, λ
I	0.28	61.33	8	49.22	1.63
II	0.17	73.09	12.96	60.33	0.95
III	0.19	69.8	18.8	51.0	1.12
IV	0.21	71.8	21.34	50.46	1.37
V	0.2	72.73	23.8	48.93	2 05

It is most expedient to determine the thermal conductivity of the aggregate by testing in concrete, i.e. by comparing the thermal conductivity of concrete on different porous aggregates with a constant volume concentration and composition of the solution. To calculate the thermal conductivity of a light filler based on these data, one can use the theoretical dependencies derived in thermophysics for the thermal conductivity of two-phase systems [10, 11].

In these dependencies related to granular or cellular materials, thermal conductivity is considered as a function of the thermal conductivity of the solid phase, the gas filling the intergranular space or located in the pores and porosity of the system.

Light concrete can be likened to a two-phase grain system, where the grain of the aggregate is solid phase particles, and the mortar component is the intergranular space (then the volume concentration of the aggregate will be numerically equal to $C_з$ =1-P, where P - porosity of the system), or a cellular system, where the grains of the aggregate are pores, and the solution is solid (in this case $C_з$ = P).

Table 2. Comparison of experimental and calculated values

№	The equation	Literary sources	Average deviation from the theoretical,%		The standard deviation of theoretical, from experimental ,%	
			In the dry state	By W_{o6}=10%	In the dry state	By W_{o6}=10%
1	2	3	4	5	b	7
1	$\lambda_b = \lambda_p \frac{1}{\frac{\lambda_p}{\lambda_з} C_з + 1 - C_з}$	[12, 13]	-4.1	-4.1	8.2	9
2	$\lambda_b = \lambda_з C_з + \lambda_p(1 - C_з)$	[12, 13]	3.3	0.7 .	6.8	7.3

Continuation of table № 2.

	The equation	Literary sources	Average deviation from the theoretical,%		The standard deviation of theoretical, from experimental,%	
			In the dry state	By W₀₆=10%	In the dry state	By W₀₆=10%
3	$\lambda_b = \lambda_p \frac{4(1-C_3)}{1+\frac{\lambda_p}{\lambda_3}} + \lambda_3(2C_3 - 1)$	[12, 13]	-6	-5.5	10.5	10.7
4	$\lambda_b = \lambda_p \frac{4C_3}{1+\frac{\lambda_p}{\lambda_3}} + \lambda_p (1- 2C_3)$	[12, 13]	-2.3	-2.7	6.6	8.3
5	$\lambda_b = \lambda_p \frac{C_3^{2/3}+\frac{\lambda_p}{\lambda_3}+(1-C_3^{2/3})}{C_3^{2/3}- C_3 +\frac{\lambda_p}{\lambda_3}(1-C_3^{2/3}+C_3)}$	[12, 13]	2.2	0.8	6.6	8,9
6	$\lambda_b = \lambda_3 C_3^{2/3} + \lambda_3(1- C_3^{2/3})$	[13]	1.3	-1,4	7.3	6.2
7	$\lambda_b=\lambda_3(1-1.1C_3^{2/3}) + 1,1\lambda_3 C_3^{2/3}$	[14]	1,6	1,2	5.3	5.4
8	$\lambda_b = \lambda_3\frac{2\lambda_p+ \lambda_3- 3C_3(\lambda_p- \lambda_3)}{2\lambda_p+ \lambda_3+ C_3(\lambda_p- \lambda_3)}$	[12]	1.1	-1.0	5.0	5,1
9	$\lambda_b = \lambda_p\frac{2\lambda_p+ \lambda_3- 2C_T(\lambda_p- \lambda_3)}{2\lambda_p+ \lambda_3+ C_3(\lambda_p- \lambda_3)}$	[13]	1.0	-0.1	5,5	5.7
10	$\lambda_b=\lambda_p(1- C_3^{2/3}) + \frac{\lambda_p\lambda_3 C_3^{2/3}}{\lambda_3(1- C_3^{2/3})+\lambda_p C_3^{2/3}}$	[14]	1.6	-1.3	5.8	7.3.

3 Theory and discussion

Mathematical processing of the results obtained by the least squares method showed (Table 2) that elementary models constructed on the principle of alternating (parallel or perpendicular to the heat flow) plates (formulas (1), (2)) do not give a satisfactory result. Sufficiently good data were obtained using formulas (8), (9) obtained by Rayleigh on the basis of the Maxwell-Burgel-Eiken theory, proceeding from the principle of the electrothermal analogy for spherical particles uniformly distributed in a dense medium.

Having solved equation (9) with respect to λз, we obtain a formula for calculating the thermal conductivity coefficient of a filler (expanded clay) when tested in concrete

$$\lambda_3 = \lambda_p \frac{C_p(2\lambda_p+ \lambda_3)- 2(\lambda_p+\lambda_3)}{C_p(\lambda_p+ \lambda_3)+ (\lambda_p+ \lambda_3)} \quad (1)$$

Having determined the values of λ_p and λ_z, and then λ_z in dry and wet conditions, it is possible to calculate the value of $K_{ВЛ}$ he tested light filler by the formula

$$K_{WET} = \lambda_p \frac{\lambda_{wet}- \lambda_{dry}}{W_{ob}} \cdot 100 \quad (2)$$

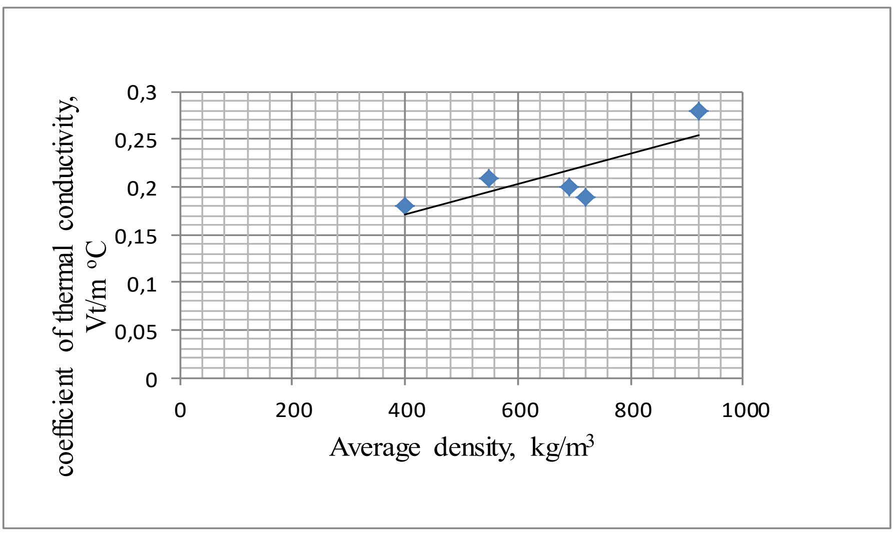
Satisfactory results were given by formula (7). The coefficient of thermal conductivity of the filler in this case is calculated by the formula

$$\lambda_3 = \frac{\lambda_b - \lambda_p(1 - C_3^{2/3})}{C_3^{2/3}} \quad (3)$$

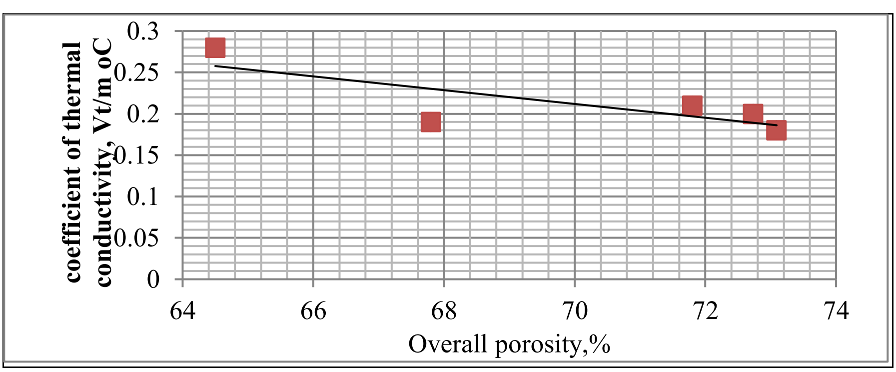
Using these formulas, the data of experiments on the testing of cinderamsite in concrete were processed and the values of the thermal conductivity coefficients of cinderamsite were determined for the first time. At the same time, it turned out that the values of λ3 in the dry and wet states, determined by two different formulas, are close to each other, which made it possible to carry out their subsequent averaging.

In order to identify the relationship between the thermal conductivity of ash-ceramsite with its average density and the parameters of the pore structure, graphical dependencies were constructed (Fig. 1,2).

As can be seen from the presented data (Fig. 1), the dependence of the coefficient of thermal conductivity of the exhaust gas of the average density of ash-ceramsite is approximately linear and with an increase in the average density, the value of the coefficient of thermal conductivity increases



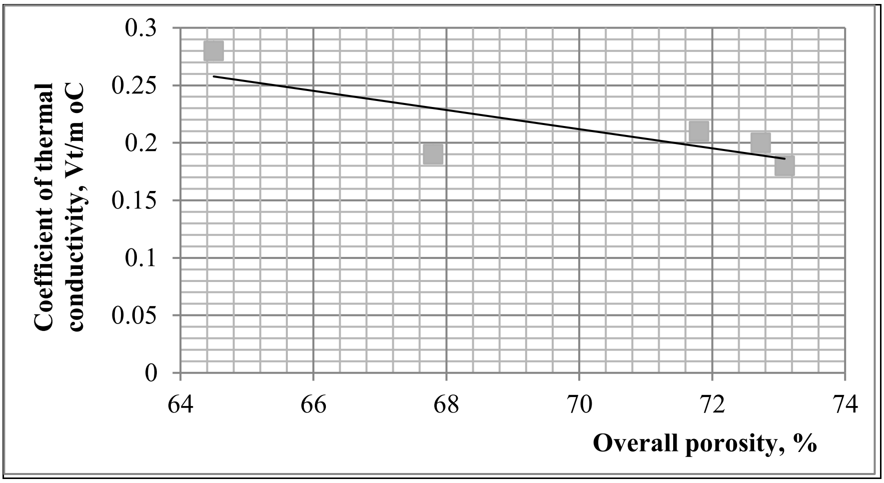
a)



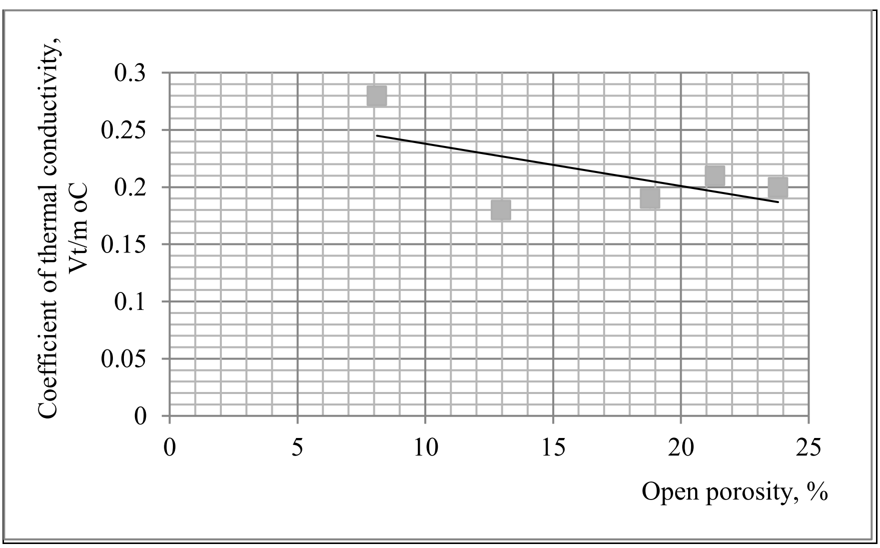
b)

Fig. 1. The dependence of the thermal conductivity coefficient of ash-ceramsite on its average density (a) and total porosity (b)

This is explained by the fact that with an increase in the average density of the ash-expanded clay, the relative content of the solid phase, which has a much higher thermal conductivity than air, also increases, which leads to an increase in the thermal conductivity coefficient of the ash. However, ash-cermets at the same average density have a diffuse thermal conductivity coefficient - This is explained by the different structure of ash-cermite, when the pores differ in their shapes, sizes and placement (Table 1)



a)



b)

Fig. 2. The dependence of the thermal conductivity coefficient of gold-ceramsite on its index of the average pore size (a) and open porosity (b).

It follows from the data presented in Fig. 2-5 that the thermal conductivity coefficient of ash-ceramsite to a greater or lesser extent depends on the parameters of its burrowing structure.

The correlation analysis of the obtained data showed that the dependence of the thermal conductivity coefficient of gold-ceramsite on the parameters of the burrow structure obeys a linear and parabolic law and is approximated, respectively, by regression equations of the form:

$$\lambda_з = a + bP \quad (4)$$

$$\lambda_з = a + b lg P \quad (5)$$

where $\lambda_з$ - coefficient of thermal conductivity of ash-ceramsite, Vt/m ºC; P – parameters of the pore structure; *a* and *b* – regression coefficients.

In table 3 regression equations obtained as a result of processing experimental data are presented.

Table 3. Equations of dependence of the thermal conductivity coefficient of ash-ceramsite on the parameters of the burrow structure

№	Regression equation	Correlation coefficient
1	$\lambda_з = 0.00052\rho - 0.105$	0.692
2	$\lambda_з = 0.794 – 0.008 P_{ob}$	0.611
3	$\lambda_з = 0.292 – 0.002 P_{от}$	0.632
4	$\lambda_з = 5.1 – 2.8\, lg\, P_b$	0.779
5	$\lambda_з = 0.061\lambda + 0.118$	0.895

A comparison of the correlation coefficients of these equations and the experimental data presented in Fig.2 shows that the most sensitive to changes in the thermal conductivity coefficient are the conditionally closed porosity and the average pore size of the ash-ceramsite. Low correlation coefficients and a significant spread of experimental data (Fig.1) indicate the unreliability of the dependence of the thermal conductivity coefficient on the average density, total and open porosity. It is obvious that at the same density, materials with a finely porous structure and evenly distributed separated pores have a lower thermal conductivity than materials with large-porous open pores, which is consistent with the general provisions of the work [15].

4 Conclusion

Thus, the results of the conducted studies show that the main factor determining thermal conductivity.a light filler, is the structure of its burrowing space. Moreover, fairly accurate information about the thermal conductivity of a porous aggregate can be obtained by the indicator of the average size of the holes and conditionally closed porosity.

The results obtained and the conclusions resulting from them are of great importance in the processing of technological modes of production of artificial porous aggregates and in the design of lightweight concrete with specified thermal characteristics.

References

1. Abbaskhanov N.A. Expanded clay concrete with the use of acetone-formaldehyde resin. Tashkent (1984).
2. V. M. Gorin, S. A.Tokareva, M. K. Kabanova Effective expanded clay concrete in Russia. Building materials. Vol. 9. - pp. 54-57. (2009).

3. Bichkov M.V., Udodov S.A. Composition, structure and properties of light structural self-sealing tuff concrete. Rostov-on-Don, (2013).
4. Sheikin A. E. Chekhov Yu. V. Structure and properties of cement concretes. Moscow (1979).
5. Bleshchik N.P. and Protko N. S. Technological and physico-mechanical properties of expanded clay concrete of dense structure, including those made of highly mobile concrete mixtures. Materials of the Third International Symposium, Problems of modern concrete and reinforced concrete, Vol. 2, pp.114-115 (2011).
6. Semenyuk S. D., Melyantsova I. I., Mamochkina M. G., Divakova G. A. Study of strength and deformability of expanded clay concrete of classes 10/12, 5 and 16/20 according to experimental data. Bulletin of the Belarusian-Russian University. Vol. 3 (44), pp.114-122 (2014).
7. Samigov N. A., Karimov M. U., Mirzaev B. K. Investigation of physical and mechanical properties of expanded clay concrete with a complex polymer mineral additive of a new generation based on local raw materials.Scientific and practical magazine "Architecture Construction Design" Spec. Issue, p. 53-56. (2019).
8. Mirzoev B. K. Structure and properties of expanded clay concrete with complex polymermineral additives on local raw materials, Tashkent (2020).
9. Mirzazhanov M. A., Abdurakhmanov A., Kotov A. I. Studies of the pore structure of a lightweight concrete filler. Abstracts of the All-Union reports. confer. Search Tashkent, pp. 103-104 (1985).
10. Vinogradov B. N. The influence of aggregates on the properties of concrete. Moscow (1979).
11. Morozov N. V., Permyakov S. I., Tuchkova N. A. Thermal properties of light concrete and enclosing structures made of them. Concrete and reinforced concrete, Vol. 3, pp. 6-8 (1967).
12. Chudnovsky A.F. Thermophysical characteristics of dispersed systems. (1962).
13. Dulnev G. I., Sigalova Z. V., Effective thermal conductivity of granular materials. Engineering and Physics Journal Vol. XIII, No. 5, 1967, pp. 17-20.
14. Baranov A.T., Bodrov O.D. New in the calculation of thermal conductivity of cellular concrete. "Building Materials", Vol. 3, pp. 22-24. (1968).
15. Campbell A.D., Thorne C.P. The thermal conductivity of concrete. Mag. Concrete research, Vol. 43, pp.33-37. (1963).