Investigation of water absorption of non-autoclaved foam concretes based on microsilica

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Abstract. The article presents the results of a study of water absorption of non-autoclaved foam concrete based on microsilica. The dependence of water absorption by mass and by volume on the average density of foam concrete in the range of 500÷700 kg/m³ is derived. It is experimentally established that the water absorption of foam concrete based on microsilica the grade D500 by mass is 100.9 %, by volume – 53.6 %, for the grade D700 – 64.3 % and 42.4 %, respectively. At the same time, a day after immersion in water, foam concrete the grade D500 gains an average of 69.7 % from full water absorption both by mass and by volume, foam concrete the grade D700 – 66.1 %. Full of water absorption of non-autoclaved foam concrete based on microsilica reaches in seven weeks later. The difference in water absorption between the grades D500 and D700 by mass is 56.9 %, by volume – 26.4 %. The closed porosity of foam concrete based on microsilica the grade D500 is 26 %, and for the grade D700 – 32.2 %.

Water absorption is the ability of a material to absorb and retain water in its pores when it comes in direct contact with it, i.e. when it is immersed.

Water absorption of materials is characterized by the ratio of the amount of water that absorbs the dry material when it is kept in water to the mass of the dry material (water absorption by mass \( W_m \)) or to the volume of the material (water absorption by volume \( W_v \)).

Many Russian and foreign researchers study the water absorption of concretes [1÷18]. It is known that water absorption is affected by the porosity of the material and the nature of its pores (open or closed pores). The greater the open porosity of the material, the higher its water absorption.

The amount of water absorption significantly affects the frost resistance of the material, and subsequently its durability.

Foam concrete is a type of cellular concrete in which porosity is created by introducing pore-forming components, in particular a foaming agent, into the concrete mixture. Therefore, the total porosity of foam concrete, depending on their average density, can reach 90% or more.

The introduction of ultrafine fillers with low bulk density, such as microsilica, into the composition of foam concrete reduces their overall porosity, which has a positive effect on the mechanical characteristics of foam concrete [19].

The aim of the work was to establish the dependence of water absorption of non-autoclaved foam concrete based on microsilica on its average density.

The following materials were used in the research:
- Portland cement of the grade CEM I 42.5 H produced by JSC «Angarskcemment»;
- microsilica from filters of dust collectors of JSC «Kremniy»;
- hyperplasticizer based on polycarboxylates «MC-Power-Flow-3100»;
- synthetic foaming agent Penta Pav 430 (grade A).

The research methodology was as follows. The foam concrete mixes for the foam concretes grades D500 and D700 was prepared using the classical technology: the mortar mix (Portland cement (PC)+microsilica (MC)+water+hyperplasticizer) and the foam (water+foaming agent) were prepared separately. Then everything was mixed until a homogeneous mass was obtained. From previously performed work, it was found that the optimal ratio of the binder (PC) to the filler (MC) in foam concrete is 1:1 [20].

Samples of 100x100x100 mm in size were made from foam concrete mixes. After 28 days of normal hardening, they were dried to a constant mass at a temperature of 105±5 °C and tested for water absorption in accordance with GOST 12730.3 Concretes. Method of determination of water absorption.

The test results are presented in table 1 and shown in figures 1÷3.

| Parameter | D500 | D700 |
|-----------|------|------|
| The average density, \( \rho_m \), kg/m\(^3\) | 531  | 660  |
| Water absorption by mass, \( W_m \), %, after |       |      |
| 1 day     | 70,3 | 42,5 |
| 7 days    | 75,8 | 49,0 |
| 14 days   | 82,3 | 53,2 |
| 21 days   | 88,0 | 57,0 |
| 28 days   | 92,6 | 60,4 |
| 35 days   | 96,5 | 62,5 |
| 42 days   | 99,5 | 63,9 |
| 49 days   | 100,9| 64,3 |
| Water absorption by volume, \( W_v \), %, after |       |      |
| 1 day     | 37,3 | 28,0 |
| 7 days    | 40,3 | 32,4 |
| 14 days   | 43,7 | 35,1 |
| 21 days   | 46,7 | 37,6 |
| 28 days   | 49,2 | 39,8 |
| 35 days   | 51,3 | 41,2 |
| 42 days   | 52,8 | 42,2 |
| 49 days   | 53,6 | 42,4 |

The results presented in table 1 show that after a day of water absorption testing, foam concrete the grade D500 gains an average of 69.7 % from full water absorption, both by mass and volume, and foam concrete the grade D700 – 66.1 %. In the future, after seven weeks of testing, the water absorption by mass and volume of foam concrete D500 increases by an average of 43.6 %, while for D700, the increase is 51.4 %. The difference in water absorption between the grades D500 and D700 by mass is 56.9 %, by volume is 26.4 %.

The change in water absorption by mass and by volume of non-autoclaved foam concrete based on microsilica depending on its average density in the range from 500 to 700 kg/m\(^3\) (figure 1) is described by the equations:

\[
W_m = 251.56 - 0.2837 \cdot x, \quad (1)
\]

\[
W_v = 99.702 - 0.0868 \cdot x, \quad (2)
\]

where \( x \) – the average density of non-autoclaved foam concrete based on microsilica, kg/m\(^3\).
Figure 1. Water absorption of non-autoclaved foam concretes based on microsilica.

Figure 2. Change in time the water absorption by mass of non-autoclave foam concretes based on microsilica.

Figure 3. Change in time the water absorption by volume of non-autoclave foam concretes based on microsilica.
The change in time the water absorption by mass and by volume of non-autoclave foam concretes based on microsilica (figures 2, 3) is described by the following equations.

For foam concrete the grade D500:
\[
W_m = 69.928 - 0.0086 \cdot x^2 + 1.0623 \cdot x \\
W_v = 37.114 - 0.0046 \cdot x^2 + 0.5665 \cdot x
\]

For foam concrete the grade D700:
\[
W_m = 42.836 - 0.0092 \cdot x^2 + 0.8882 \cdot x \\
W_v = 28.292 - 0.006 \cdot x^2 + 0.5832 \cdot x
\]

where \( x \) – the test time, day.

The amount of water absorption by volume is numerically equal to the open porosity of the material \((P_{op})\). Knowing the total and open porosity, you can calculate the closed porosity of the material.

The total porosity of materials in % is calculated by the formula:
\[
P_{tot} = \left(1 - \frac{\rho}{\rho_m}\right) \cdot 100 ,
\]

where \( \rho_m \) and \( \rho \) – the average and true densities of the material, respectively, kg/m³.

The closed porosity of the material in % is determined by the formula:
\[
P_{cl} = P_{tot} - P_{op}
\]

The values of the total, open and closed porosity of non-autoclaved foam concretes based on microsilica are shown in table 2.

| Parameter          | The grade of foam concrete |
|-------------------|---------------------------|
|                   | D500 | D700 |
| Average density, kg/m³ | 531  | 660  |
| Total porosity, %      | 79.6 | 74.6 |
| Open porosity, %       | 53.6 | 42.4 |
| Closed porosity, %     | 26.0 | 32.2 |

The results from table 2 shows that the number of closed pores in foam concrete based on microsilica the grade D700 are 23.85 % more than in the foam concrete the grade D500, while the difference in the total porosity between the foam concretes of the studied grades is only 5 %.

Thus, it is experimentally established that:
- water absorption of foam concrete based on microsilica the grade D500 by mass is 100, 9 %, by volume is 53.6 %, for the grade D700 – 64.3 % and 42.4 %, respectively;
- on the first day of the water absorption test, foam concrete the grade D500 gains an average of 69.7 % from full water absorption, both by mass and volume, and foam concrete the grade D700 – 66.1 %.

Full of water absorption of non-autoclaved foam concrete based on microsilica reaches in seven weeks later. During this time, water absorption by mass and volume of foam concrete the grade D500 increases by an average of 43.6 %, while for D700 the increase is 51.4 %;
- the difference in water absorption between the grades D500 and D700 by mass is 56.9 %, by volume is 26.4 %;
- closed porosity of non-autoclaved foam concrete based on microsilica the grade D500 is 26 %, the grade D700 is 32.2 %.

Water absorption dependences by mass and by volume of non-autoclaved foam concrete based on microsilica on its average density in the range from 500 to 700 kg/m³ have been experimentally derived.

References
1. Andreeva A V and Savvinova M E 2017 Water absorption of fine-grained concrete (Vodopogloshchenie melkozernistogo betona) XIX ISR in memory of A. A. UKHTOMSKY (XIX MNC pamyati UHTOMSKOGO A.A.) pp 19-20
2. Korovkin M O, Eroshkina N A, Teplova M F and Korovchenko I V 2015 Research on the
kinetics of water absorption of fine-grained concrete $YS \ (MU)$\textsuperscript{13} pp 132-135

[3] Hvastunov V L, Kalashnikov V I, Hvastunov AV and Pausk V V 2014 Parameters of water absorption and porosity of powder-activated high-strength concrete with low specific consumption of cement per unit of strength $RAC \ (RAS)$\textsuperscript{4} pp 45-51

[4] Fedyuk R S 2016. Investigation of water absorption of fine-grained fiber concrete on a composite binder $BR \ (FI)$\textsuperscript{2-2} pp 303-307

[5] Merzyakov A O 2019 Study of the traceability of sodium formate additive and its effect on water absorption of concrete $IS \ (IN)$\textsuperscript{1} pp 289-29

[6] Zhengyu Pan Changsheng and Lijian 2014 The influence of different hydrophobic agent on the water absorptivity of foam concrete $AMSEM$\textsuperscript{665} pp 192-195

[7] Liu C., Luo J., Li Q 2019 Water-resistance properties of high-belite sulphoaluminate cement-based ultra-light foamed concrete treated with different water repellents $CBM$\textsuperscript{228} UNSP 116798

[8] Nambiar E K Kunhanandan and Ramamurthy K 2007 Sorption characteristics of foam concrete $CCR$\textsuperscript{37} (9) pp 1341-1347

[9] Ioannou I, Hamilton A and Hall C 2008 Capillary absorption of water and n-decane by autoclaved aerated concrete $CCR$\textsuperscript{38} (6) pp 766-771

[10] Kumar E Muthu and Ramamurthy K 2017 Influence of production on the strength, density and water absorption of aerated geopolymer paste and mortar using Class F fly ash $CBM$\textsuperscript{156} pp 1137-1149

[11] Namsone E, Sahmenko G and Namsone E 2017 Reduction of the capillary water absorption of foamed concrete by using the porous aggregate $IMST \ IOP \ CS$\textsuperscript{251}

[12] Lin K-L, Lee T-C and Chang J-C 2013 Water absorption and retention of porous ceramics cosintered from waste diatomite and catalyst $EP\&SE$\textsuperscript{32} (3) pp 640-648

[13] Raj A, Sathyan D, and Mini K M 2019. Physical and functional characteristics of foam concrete $CBM$\textsuperscript{221} pp 787-799

[14] Abd Elraham M, Chung S-Y and Stephan D 2019 Effect of different expanded aggregates on the properties of lightweight concrete $MCR$\textsuperscript{71} (2) pp 95-107

[15] Karolina R and Sianipar Y C 2018 The utilization of stone ash on cellular lightweight concrete $TALENTA-CEST \ IOP \ CS$\textsuperscript{309}

[16] Guimaraes A S, Ribeiro I M and de Freitas V P 2017 A tool to predict water absorption in porous building materials $JPM$\textsuperscript{20} (2) pp 127-141

[17] Dachowski R and Kostrzewa P 2016 The use of waste materials in the construction industry $WMCAUS\ PE$\textsuperscript{161} pp 754-758

[18] Jitchayaphum K, Sinsiri T and Jaturapitakkul C 2013 Cellular lightweight concrete containing high-calcium fly ash and natural zeolite $IJMMM$\textsuperscript{20} (5) pp 462-471

[19] Baranova A, Shustov P and Yazina O 2018 Structural and heat-insulating foam concrete of non-autoclaved hardening based on microsilica $MATEC \ WoC$\textsuperscript{212} N article 01003

[20] Baranova A and Ryabkov I 2019 Investigation of thermal conductivity of non-autoclaved foam concrete based on microsilica $IOP \ CS$: M$SaE$\textsuperscript{67} N 1