Water absorption of cellular concretes made on the basis of technogenic raw materials

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Abstract. The article presents a comparative analysis of water absorption of non-autoclaved foam concretes based on microsilica and autoclaved aerated concretes based on fly ash. It is experimentally established that the water absorption by mass of foam concrete the grade D500 is 19.6 % higher than that of aerated concrete of the same grade. Open porosity, which is numerically equal to water absorption by volume, is also higher for non-autoclaved foam concrete by 30.1 %. Closed porosity for autoclaved aerated concretes based on fly ash the grade D500 is 53.9 % higher compared to non-autoclaved foam concrete of the same grade. The dependences of open and closed porosity of cellular concretes based on technogenic raw materials on their average density are experimentally derived. In the course of research, it was determined that water absorption, open and closed porosity of cellular concretes at the same average density depends on the type of aggregate and on the hardening conditions.

Cellular concretes due to its porous structure are belonging to be energy-efficient building materials. The use of man-made waste in their production allows not only to improve the mechanical characteristics and reduce the cost of production, but also to solve a number of environmental problems.

For cellular concretes, average density and porosity are important indicators. The decrease in density due to the increase in porosity leads to increased water absorption of the material (40÷50 % by volume or more), which increases the thermal conductivity and reduce the thermal insulating abilities. And from the ability of the enclosing structure to absorb and retain humidity depends on its strength and frost resistance. The smaller the amount of humidity it can absorb a block from the cellular concrete is, the better his performance.

Depending on the porosity formation method, cellular concretes are divided into aerated concretes obtained by introducing gas-forming agents into the solution mixture, and foam concretes produced using pre-prepared foam.

Under the conditions of hardening, cellular concretes is divided into autoclaved and non-autoclaved. Autoclaved cellular concretes gain strength under saturated steam conditions in autoclaves at a temperature of 175±195 °C and a pressure of 0.8÷1.2 MPa for 10÷12 hours. Non-autoclaved cellular concretes hardens in natural conditions at a temperature of 20±2 °C and a humidity of 95÷100 % for 28 days [1].

Many works of Russian and foreign authors have been devoted to the study of concretes water absorption [2÷21]. The properties of cellular concretes depend on many factors: the structure (pore content, uniformity of their distribution), the method of pore formation and their size, the type of binders.
and other components of the composition, and the conditions of hardening. It is known that aerated concrete has both closed and open pores, and foam concrete has mostly closed porosity.

The aim of the work was to determine and compare water absorption, open and closed porosity of autoclaved aerated concretes based on fly ash and non-autoclaved foam concretes based on microsilica.

The following materials were used in the research:
- Portland cement of the grade CEM I 42.5 H produced by JSC «Angarskcement»;
- 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).
- blocks of autoclaved aerated concretes based on fly ash of the grades on average density D500 and D600 produced by CJSC «Stroikompleks».

The research methodology was as follows. Samples of non-autoclaved foam concrete based on microsilica of the grades D500 and D700 with dimensions of 100x100x100 mm were manufactured in a laboratory using classical technology and gained strength for 28 days in chamber of normal hardening [22, 23].

Samples of 50x100x100 mm in size were cut from blocks of autoclaved aerated concretes based on fly ash [24].

Then all samples of cellular concrete 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 tables 1÷2 and shown in figures 1÷4.

**Table 1.** Water absorption of cellular concrete samples.

| Parameter                                      | The grade of foam concrete | The grade of aerated concrete |
|------------------------------------------------|---------------------------|-----------------------------|
|                                                | D500  | D700  | D500  | D600  |
| The average density, \( \rho_{\text{m}} \), kg/m³ | 531   | 660   | 490   | 603   |
| Water absorption by mass, \( W_{\text{m}} \), %, after |       |       |       |       |
| 1 day                                          | 70.3  | 42.5  | 63.6  | 56.4  |
| 7 days                                         | 75.8  | 49.0  | 69.8  | 59.5  |
| 14 days                                        | 82.3  | 53.2  | 75.5  | 62.8  |
| 21 days                                        | 88    | 57.0  | 76.7  | 65.8  |
| 28 days                                        | 92.6  | 60.4  | 77.8  | 66.8  |
| 35 days                                        | 96.5  | 62.5  | 81.3  | 70.3  |
| 42 days                                        | 99.5  | 63.9  | 83.0  | 71.1  |
| 49 days                                        | 100.9 | 64.3  | 84.4  | 72.0  |
| Water absorption by volume, \( W_{\text{v}} \), %, after |       |       |       |       |
| 1 day                                          | 37.3  | 28.0  | 31.1  | 34.0  |
| 7 days                                         | 40.3  | 32.4  | 34.1  | 35.9  |
| 14 days                                        | 43.7  | 35.1  | 36.9  | 37.9  |
| 21 days                                        | 46.7  | 37.6  | 37.6  | 39.7  |
| 28 days                                        | 49.2  | 39.8  | 38.7  | 40.3  |
| 35 days                                        | 51.3  | 41.2  | 39.8  | 42.4  |
| 42 days                                        | 52.8  | 42.2  | 40.5  | 42.8  |
| 49 days                                        | 53.6  | 42.4  | 41.2  | 43.4  |
The values of water absorption by mass and volume, as well as the total, open and closed porosity of autoclaved aerated concretes based on fly ash and non-autoclaved foam concretes based on microsilica after seven weeks of testing are presented in Table 2 and shown in Figures 3-4.

Table 2 shows that water absorption by mass in non-autoclaved foam concrete based on microsilica the grade D500 is 19.6 % higher than in autoclaved aerated concrete based on fly ash of the same grade. Open porosity, which is numerically equal to water absorption by volume, is also higher for non-autoclaved foam concrete by 30.1 %. Closed porosity of autoclaved aerated concrete based on fly ash the grade D500 is 53.9 % higher compared to non-autoclaved foam concrete of the same grade.

Table 2. Water absorption and porosity of cellular concretes.
| Parameter                           | The grade of foam concrete | The grade of aerated concrete |
|------------------------------------|----------------------------|------------------------------|
|                                    | D500 | D700 | D500 | D600 |
| The average density, $\rho_{m}$, kg/m$^3$   | 531  | 660  | 490  | 603  |
| Water absorption by mass, $W_{m}$, %       | 100.9| 64.3 | 84.4 | 72.0 |
| Water absorption by volume, $W_{v}$, %     | 53.6 | 42.4 | 41.2 | 43.4 |
| Total porosity, $P_{tot}$, %              | 79.6 | 74.6 | 81.2 | 76.8 |
| Open porosity, $P_{op}$, %                | 53.6 | 42.4 | 41.2 | 43.4 |
| Closed porosity, $P_{cl}$, %              | 26.0 | 32.2 | 40.0 | 33.4 |

Figure 3. Dependence of open porosity from the average density of cellular concretes.

Figure 4. Dependence of closed porosity from the average density of cellular concretes.
Changes in the open and closed porosity of cellular concretes depending on their average density (figures 3, 4) are described by the following equations.

For autoclaved aerated concrete based on fly ash:

\[
P_{op} = 31.66 + 0.0195 \cdot x, \tag{1}
\]

\[
P_{cl} = 68.619 - 0.0584 \cdot x. \tag{2}
\]

For non-autoclaved foam concrete based on microsilica:

\[
P_{op} = 99.702 - 0.0868 \cdot x, \tag{3}
\]

\[
P_{cl} = 0.4791 + 0.0481 \cdot x, \tag{4}
\]

where \(x\) – is the average density of cellular concretes, kg/m\(^3\).

Thus, it is experimentally established that:

- the water absorption by mass of non-autoclaved foam concrete based on microsilica the grade D500 is 19.6 % higher than that of autoclaved aerated concrete based on fly ash of the same grade;
- open porosity, numerically equal to water absorption by volume, is also higher for non-autoclaved foam concrete by 30.1 %;
- closed porosity of autoclaved aerated concrete based on fly ash the grade D500 is higher by 53.9 % compared to non-autoclaved foam concrete of the same grade.

The dependence of open and closed porosity of cellular concretes based on technogenic raw materials from their average density has been established experimentally. A comparative analysis of water absorption of autoclaved aerated concrete based on fly ash with non-autoclaved foam concrete based on microsilica is performed. In the course of research, it was determined that water absorption, open and closed porosities of cellular concretes at the same average density depends on the type of aggregate and on the hardening conditions.

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