Comparative analysis of the strength of normal adhesion of a masonry from aerated concrete blocks of autoclave hardening, performed on various cement and polymer-cement mortars

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Abstract. The article presents the results of experimental studies of determining the strength of normal adhesion (with axial tension) in a masonry of cellular concrete blocks of autoclave hardening of classes of compressive strength B1.5 ÷ B3.5 in various cement and polymer-cement mortars. The tests were carried out in the Laboratory of the Department of «Reinforced Concrete and Stone Structures» of Moscow State University of Civil Engineering on experimental samples consisting of two cubes 150x150x150 mm in size, sawn from aerated concrete blocks and bonded (glued) to each other using masonry mortars. The analysis of the research results is carried out and the value of the percentage increase in the normal adhesion in the masonry is determined when polymer cement compositions are used in the masonry joints instead of cement masonry mortars.

At present, on the territory of the Russian Federation, when laying walls of buildings, masonry from cellular concrete blocks of autoclave hardening is widely used. Such popularity of aerated concrete masonry is due to several advantages compared to ceramic brick masonry: high thermal insulation properties, high fire safety, relatively low weight of blocks, a large assortment of sizes and shapes, as well as an easier and more accurate laying process. Aerated concrete blocks are used, first of all, for the construction of external and internal walls of residential buildings, shops, office buildings. According to the design, the walls of this material can be both load-bearing (walls of private low-rise houses, cottages, shops), and non-bearing (external walls and partitions of high-rise residential and office buildings). Therefore, when designing walls of small cellular concrete blocks, it is necessary to be guided by the requirements of SP 15.13330.2012 «Stone and reinforced stone structures». In this standard, the dominant role among the indicators of the strength of the masonry is the calculated resistance to compression of the masonry R, which characterizes its compressive strength. However, there is an equally significant indicator - the calculated axial tensile strength Rt, which characterizes its axial tensile strength, and plays an important role in determining the normal adhesion of the mortar mixture with cellular concrete blocks and, as a consequence, in determining the monolithicity of the masonry.

In the period from 2018 to 2019, a series of tests were carried out at the Laboratory of the Department of Reinforced Concrete and Stone Structures of Moscow State University of Civil Engineering to determine the normal adhesion of masonry from cellular concrete autoclave blocks
made on various cement and polymer-cement mortars. Normal adhesion in the masonry was determined on prototypes in accordance with the requirements of GOST 24992-2014 «Stone structures. Methods for determining the adhesion strength in masonry» by testing them for axial tension. The essence of the method is to determine the characteristics of the specific work for the separation of the block and the solution under the action of an axial tensile force directed perpendicular to the plane of their contact (along untied seams). For testing prototypes, the corresponding machine for testing materials in tension, compression and bending was used that meets the requirements of GOST 28840-90 «General technical requirements» WDW-300E electromechanical universal testing machine with a maximum load of 300 kN and grippers. The scheme of axial tensile testing of samples is presented in Figure 1.

The prototype is two cubes measuring 150x150x150 mm, sawn from aerated concrete blocks and bonded (glued) to each other in the laboratory using masonry mortars (Figure 2). On each block were cut grooves measuring 20x20 mm under the gripper. Before applying the binder solutions, all samples were thoroughly dedusted. According to the recommendations of some manufacturers of adhesives, the adhesion sites of the samples were moistened with a small amount of water. Polymer-cement mortars were applied in such a way as to ensure a mortar joint thickness of 3-5 mm, cement mortars -10-12 mm. The glued experimental ones were kept for 28 days under normal heat and humidity conditions under low pressure (about 9-10 kg) to ensure better adhesion of the binder to the surface of the cellular concrete.

Figure 1. Axial tensile test design

Figure 2. Sizes of prototypes for axial tensile testing

In the tests, blocks of various strengths were used, which corresponded to concrete classes in compressive strength: B1.5, B2.5, B3.5. Before the axial tensile tests of the prototypes, compression tests of cubes of cellular concrete with dimensions of 150x150x150 mm were carried out in order to determine the class of concrete in terms of compressive strength in accordance with the requirements of GOST 10180-90 «Concretes. Methods for determining the strength of control samples» (Figure 3), as well as testing cubes from various solutions with dimensions of 70.7x70.7x70.7 mm according to the method of GOST 5802-86 «Building solutions. Test methods» to determine their strength (Figure 4). These tests guaranteed the use in test samples for axial tensile testing of cubes of the required concrete class (B1.5, B2.5, B3.5) and masonry mortar with a known value of compressive strength.
The following compositions were used as masonry mortar:

Series No. 1 - cement-sand mortar M200.
Series No. 2 - cement-sand mortar M300.
Series No. 3 - glue for cellular concrete blocks «SR-67 PRO».
Series No. 4 - mounting glue «Sibir».
Series No. 5 - cement mounting adhesive «Axton».
Series No. 6 - mounting glue for blocks «Bolars».
Series No. 7 - glue for blocks «Super Titan».

Thus, in each series, nine prototypes were made: three on cubes of concrete B1.5, three on cubes of concrete B2.5, three on cubes of concrete B3.5. In total, the comparative analysis used data on the results of tests of 63 samples.

**Figure 3.** Aerated concrete cubes samples after compression test

**Figure 4.** Samples of cubes from masonry mortar after compression test

In the experiment, a rigid grip scheme was used, in which it is allowed to use the supporting parts of the testing machine, provided that these parts provide a coaxial transmission between them (parts) of the tensile force. To ensure coaxiality of the transfer of force between the grippers, they were connected to the supporting devices of the testing machine through the Hook joint. The end element was installed in the supporting device of the testing machine.

Before each installation of a new sample in the testing machine, the concrete parts from the remaining from the previous test in the grips were removed. The maximum force achieved during the test was taken as the breaking load, and the strength of the normal adhesion of the masonry $R_{ut}$ (temporary resistance to axial tension) was determined by the formula (1) GOST 24992-2014:

$$R_{ut} = \frac{F}{A}$$

(1)

where, $F$ - is the breaking load (N);
$A$ - total separation area (mm$^2$).

The tensile strength of normal adhesion (with axial tension) in the masonry in each series of prototypes $R_{utcp}$ (average value of the temporary resistance to axial tension) was determined as the
arithmetic average of all tested samples of the series for one type of concrete in compressive strength, i.e. as the arithmetic mean of the test results of 3 samples.

The transition from the average value of temporary axial tensile strength to the average value of the calculated axial tensile strength was carried out in accordance with the requirements of SP 15.13330.2012 by using the coefficient $k = 2.2$:

$$ R_t = \frac{R_{ut}}{k} $$ (2)

An analysis of the results of experimental studies of determining the strength of normal adhesion (with axial tension) in the masonry of cellular concrete autoclave blocks on various cement and polymer-cement mortars (see tables 1 and 2) allows us to draw the following conclusions:

1. When using autoclave hardening classes of cellular strength concrete blocks of compressive strengths B1.5, B2.5 and B3.5 of various polymer-cement (adhesive) mortars instead of cement mortars of the M200 grade, the calculated axial tensile strength over the non-bound section (normal adhesion) masonry increases, respectively, by 2–28% (B1.5), 30–48% (B2.5) and 28–46% (B3.5).

| Table 1. Axial tensile test results of prototypes (normal adhesion). |
|---------------------------------------------------------------|
| Masonry mortar series | The average value of the axial tensile strength, $R_{ut}(cp)$ (kPa) | The average value of the calculated axial tensile strength, $R_t(cp)$ (kPa) | Strength increase relative to series No. 1, (%) |
|----------------------|-------------------------------------------------|-----------------------------------|------------------|
| Aerated concrete block of compressive strength class B1.5     |
| Series No. 1         | 102,7                                          | 46,7                             | -                |
| Series No. 3         | 104,5                                          | 47,5                             | 2                |
| Series No. 4         | 121,2                                          | 55,1                             | 18               |
| Series No. 5         | 115,0                                          | 52,3                             | 12               |
| Series No. 6         | 131,4                                          | 59,7                             | 28               |
| Series No. 7         | 113,2                                          | 51,5                             | 10               |
| Aerated concrete block of compressive strength class B2.5     |
| Series No. 1         | 142,5                                          | 64,8                             | -                |
| Series No. 3         | 185,4                                          | 84,3                             | 30               |
| Series No. 4         | 199,8                                          | 90,8                             | 40               |
| Series No. 5         | 210,4                                          | 95,6                             | 48               |
| Series No. 6         | 196,8                                          | 89,5                             | 38               |
| Series No. 7         | 194,2                                          | 88,3                             | 36               |
| Aerated concrete block of compressive strength class B3.5     |
| Series No. 1         | 159,7                                          | 72,6                             | -                |
| Series No. 3         | 204,6                                          | 93,0                             | 28               |
| Series No. 4         | 224,0                                          | 101,8                            | 40               |
| Series No. 5         | 227,8                                          | 103,5                            | 43               |
| Series No. 6         | 230,9                                          | 105,0                            | 45               |
| Series No. 7         | 233,3                                          | 106,0                            | 46               |

2. When using autoclave hardening blocks of cellular concrete blocks of compression strength classes B1.5, B2.5 and B3.5 in various polymer-cement (adhesive) mortars instead of cement mortars of the M300 grade, the calculated axial tensile strength over the non-bound section (normal adhesion) masonry increases respectively by $0 \div 26\%$, $27 \div 44\%$ and $24 \div 42\%$. 
Table 2. Axial tensile test results of prototypes (normal adhesion).

| Masonry mortar series | The average value of the axial tensile strength, $R_{ut}$ (cp) (kPa) | The average value of the calculated axial tensile strength, $R_t$ (cp) (kPa) | Strength increase relative to series No. 2, (%) |
|-----------------------|---------------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------|
| Aerated concrete block of compressive strength class B1.5      |                                                               |                                                               |                                               |
| Series No. 2          | 104,3                                                         | 47,4                                                          | -                                             |
| Series No. 3          | 104,5                                                         | 47,5                                                          | 0                                             |
| Series No. 4          | 121,2                                                         | 55,1                                                          | 16                                            |
| Series No. 5          | 115,0                                                         | 52,3                                                          | 10                                            |
| Series No. 6          | 131,4                                                         | 59,7                                                          | 26                                            |
| Series No. 7          | 113,2                                                         | 51,5                                                          | 9                                             |
| Aerated concrete block of compressive strength class B2.5      |                                                               |                                                               |                                               |
| Series No. 2          | 146,4                                                         | 66,5                                                          | -                                             |
| Series No. 3          | 185,4                                                         | 84,3                                                          | 27                                            |
| Series No. 4          | 199,8                                                         | 90,8                                                          | 37                                            |
| Series No. 5          | 210,4                                                         | 95,6                                                          | 44                                            |
| Series No. 6          | 196,8                                                         | 89,5                                                          | 35                                            |
| Series No. 7          | 194,2                                                         | 88,3                                                          | 33                                            |
| Aerated concrete block of compressive strength class B3.5      |                                                               |                                                               |                                               |
| Series No. 2          | 164,3                                                         | 74,7                                                          | -                                             |
| Series No. 3          | 204,6                                                         | 93,0                                                          | 24                                            |
| Series No. 4          | 224,0                                                         | 101,8                                                         | 36                                            |
| Series No. 5          | 227,8                                                         | 103,5                                                         | 39                                            |
| Series No. 6          | 230,9                                                         | 105,0                                                         | 41                                            |
| Series No. 7          | 233,3                                                         | 106,0                                                         | 42                                            |

3. The axial tensile strength along the untied section (normal adhesion) of masonry from cellular concrete blocks of autoclave hardening of class B1.5, made on cement and polymer-cement compositions below the normalized value presented in table 11 of SP 15.13330.2012 «Stone and stone-stone structures». Thus, the use in a masonry of cellular concrete blocks of autoclave hardening of a class of compressive strength B1.5 of polymer-cement (adhesive) solutions is impractical.
4. Samples made on cement-sand mortars of brands M200 and M300 showed, according to the test results, the lowest values of masonry resistance under axial tension. The nature of their destruction (all samples were destroyed along the seam) shows that the adhesion of such compounds to the masonry material is insufficient, and does not depend on the strength of the masonry mortar (Figure 5).

5. The nature of the destruction of samples made on a polymer-cement mortar (destruction occurred along the body of concrete), indicates the solidity of the masonry (Figure 6).

6. The nature of the destruction of the samples and analysis of the test results allows us to conclude that the axial tensile strength over the untied section (normal adhesion) of the masonry depends on the axial tensile strength of the material from which the block is made, and not on the compressive strength of the masonry mortar used, as indicated in table 11 of the SP 15.13330.2012 «Stone and reinforced-stone structures». This factor must be taken into account when calculating the masonry of cellular concrete blocks of autoclave hardening on polymer-cement (adhesive) solutions.

References
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