Increasing the Solidity of Masonry Walls Made of Cellular Concrete Blocks of Autoclave Hardening by using Polyurethane Foam Adhesive Composition as a Masonry Solution

B K Dzhamuev
Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia
dbk-07@mail.ru

Abstract. The article presents the results of experimental studies of determining the strength of normal adhesion (under axial tension) in the masonry of cellular concrete blocks of autoclave hardening classes for compressive strength B1.5 ÷ B3.5 on various cement solutions and polyurethane foam adhesives. 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 representing two cubes of 150x150x150 mm in size, sawn out of cellular concrete blocks and bonded (glued) together using masonry (binding) compositions. The analysis of research results was performed and the value of the percentage of increase in normal adhesion in masonry when using polyurethane foam adhesives in masonry joints instead of cement masonry solutions was determined.

1. Introduction
Currently on the territory of the Russian Federation in the construction of walls of buildings is widely used masonry from cellular concrete blocks autoclaved manufactured according to GOST 31360-2007 «Wall unreinforced products of cellular autoclave concrete. Technical conditions». This popularity of aerated concrete masonry is due to a number of advantages compared to masonry made of ceramic bricks: high thermal insulation properties, a high degree of fire safety, relatively light weight of blocks, a large range of sizes and shapes, as well as an easier and more precise installation process. Cellular concrete blocks are used primarily for the construction of external and internal walls of residential buildings, shops, and office buildings. By design, walls made of this material can be both load-bearing (walls of private low-rise buildings, cottages, shops) and non-load-bearing (external walls and partitions of high-rise residential and office buildings). Therefore, when designing walls made of small cellular concrete blocks, it is necessary to follow the requirements of SP 15.13330.2012 «Stone and reinforced stone structures». In this standard, the main role among the indicators of masonry strength is taken by the calculated compression resistance of masonry «R», which characterizes its compressive strength. However, there is an equally significant indicator—the calculated resistance to axial stretching «Rt», which characterizes its strength under axial tension, and plays an important role in determining the normal adhesion of the mortar mixture with cellular concrete blocks and, as a result, in determining the solidity of masonry [1-4].

When building walls, a variety of compositions are used as a binding element (masonry mortar) for laying blocks: cement-sand and polymer-cement solutions, as well as polyurethane foam adhesive compositions. However, many manufacturers of aerated concrete blocks do not recommend using
cement-sand solutions for the construction of walls, justifying this by a number of disadvantages of masonry on cement-sand solutions, such as a large seam thickness (10-12 mm); a long period of preparatory work, from sifting sand to mixing, which increases the time of work; significant dustiness of work; the presence of «wet» processes on the construction site, which make work at low temperatures: the mixture should be kneaded in small portions or continuously to heat; the presence of cold bridges in place of the masonry joints, and this additional heat loss; the heterogeneity of the solution depends not only on the quality of preparation of the solution and the technology of its application. This leads to the fact that the blocks under vertical loads on the masonry, in addition to compression, also experience bending and as a result, the strength of the masonry is significantly reduced.

All these disadvantages of masonry on a cement solution, as shown by various authors [5-7], can be avoided by using polymer-cement solutions or polyurethane foam adhesives as a masonry solution. But the question remains, how the replacement of a widespread cement-sand masonry solution with a polymer-cement or adhesive composition will affect the solidity of the masonry.

In addition to the already known research Vishnevsky A. A., Granovsky A. V., Grinfeld G. I., Derkach V. N. etc. [8-15] in the period from 2018 to 2019 in the Laboratory of the Department of «Reinforced Concrete and Stone Structures» of Moscow State University of Civil Engineering conducted a series of tests with the definition of normal adhesion strength of masonry from cellular concrete blocks autoclaved done at various cement and polymer solutions, as well as a polyurethane adhesive compositions. The results of a comparative analysis of the strength of normal adhesion of masonry made of cellular concrete blocks of autoclave hardening, made on various cement and polymer-cement solutions are published in articles [16-18].

2. Methodology

Normal adhesion in masonry was determined on prototypes in accordance with the requirements of GOST 24992-2014 «Stone structures. Methods for determining the strength of adhesion in masonry» by testing them for axial tension. The essence of the method is to determine the specific performance characteristics for separating the block and the solution under the action of an axial tensile force directed perpendicular to the plane of their contact (along non-tied seams). For testing of prototypes, Machines for testing materials for tension, compression and bending that meet the requirements of GOST 28840-90 «General technical requirements» electromechanically universal testing machine WDW-300E with a maximum load of 300kN and gripping devices. The scheme of testing samples for axial tension is shown in Figure 1.

![Figure 1](image1.png)

**Figure 1.** Axial tensile test design

![Figure 2](image2.png)

**Figure 2.** Sizes of prototypes for axial tensile testing

The prototype consists of two cubes with dimensions of 150x150x150 mm, cut from cellular concrete blocks and bonded (glued) together in the laboratory using binding solutions (Figure 2). On each block, 20x20 mm slots were cut for the gripper device. All samples were thoroughly dusted before applying the binding solutions. The bonded materials 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 solution to the surface of cellular concrete.

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 «Concrete. 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.

![Figure 3. Aerated concrete cubes samples after compression test](image1)

![Figure 4. Samples of cubes from masonry mortar after compression test](image2)

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 coaxially 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.

### 3. Results and Discussion

In the experiment, the following compositions were used as a masonry (binding) solution (column 1 of the table 1):

- Series No.1 - cement-sand solution M200.
- Series No.2 - cement-sand solution M300.
- Series No.3 - polyurethane foam glue "Tytan Professional".
- Series No.4 - polyurethane foam glue "TECHNONICOL".
- Series No.5 - polyurethane foam glue "Bonolit".
- Series No.6 - polyurethane foam glue "KUDO".

Thus, in each series, nine prototypes were produced: three on B1.5 concrete cubes, three on B2.5 concrete cubes, three on cubes of concrete B3.5. In total, the comparative analysis used data on the results of tests of 54 samples.

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:

$$R_{Ut} = \frac{F}{A}$$  \hspace{1cm} (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 $R_{Ut}(av)$ (average value of the temporary resistance to axial tension - column 2 of the table 1) 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 $k = 2.2$ (column 3 of the table 1):

$$R_t = \frac{R_{Ut}}{k}$$  \hspace{1cm} (2)

The fourth column of the table shows the values of increasing the strength of normal adhesion as a percentage relative to series No.1.

**Table 1.** Axial tensile test results of prototypes (normal adhesion).

| Masonry mortar series | The average value of the axial tensile strength, $R_{Ut}(av)$ (kPa) | The average value of the calculated axial tensile strength, $R_{t}(av)$ (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. 2          | 104.3                                                        | 47.4                                                            | 1                                             |
| Series No. 3          | 117.9                                                        | 53.6                                                            | 15                                            |
| Series No. 4          | 114.3                                                        | 52.0                                                            | 11                                            |
| Series No. 5          | 116.0                                                        | 52.7                                                            | 13                                            |
| Series No. 6          | 112.0                                                        | 50.9                                                            | 9                                             |
| Aerated concrete block of compressive strength class B2.5  |
| Series No. 1          | 142.5                                                        | 64.8                                                            | -                                             |
| Series No. 2          | 146.4                                                        | 66.5                                                            | 3                                             |
| Series No. 3          | 185.8                                                        | 84.5                                                            | 30                                            |
| Series No. 4          | 172.3                                                        | 78.3                                                            | 21                                            |
| Series No. 5          | 178.6                                                        | 81.2                                                            | 25                                            |
| Series No. 6          | 156.5                                                        | 71.1                                                            | 10                                            |
| Aerated concrete block of compressive strength class B3.5  |
| Series No. 1          | 159.7                                                        | 72.6                                                            | -                                             |
| Series No. 2          | 164.3                                                        | 74.7                                                            | 3                                             |
| Series No. 3          | 187.1                                                        | 85.0                                                            | 17                                            |
| Series No. 4          | 199.5                                                        | 90.7                                                            | 25                                            |
| Series No. 5          | 187.9                                                        | 85.4                                                            | 18                                            |
| Series No. 6          | 174.5                                                        | 79.3                                                            | 9                                             |
4. Conclusion
Analysis of the results of experimental studies to determine the strength of normal adhesion (under axial tension) in the masonry of cellular concrete blocks of autoclave hardening on various cement solutions and polyurethane foam adhesives (see table 1) allows us to draw the following conclusions:

– Samples made on cement-sand solutions of the M200 and M300 brands showed the lowest values of masonry resistance under axial tension according to the test results. The nature of their destruction (all samples were destroyed along the seam) shows that the adhesion of such compositions to the masonry material is insufficient, and does not depend on the strength of the masonry solution (Figure 5).

– An increase in the compressive strength of masonry cement mortar from M200 to M300 leads to an increase in the strength of masonry axial stretching over an unbound section by 1÷3 %, which is insignificant and is within the measurement error.

– When using in masonry of cellular concrete blocks of autoclave hardening classes for compressive strength B1.5, B2.5 and B3.5 different polyurethane foam adhesive compositions instead of cement solutions of the M200 brand, the calculated resistance to axial stretching over an unbound cross-section (normal adhesion) of the masonry increases by 9÷15 % (B1.5), 10÷30 % (B2.5) and 9÷25 % (B3.5), respectively.

– The axial tensile strength of non-bonded cross-section (normal adhesion) of masonry made of cellular concrete blocks of autoclave hardening class B1.5, made on cement and adhesive compositions below the normalized value presented in table 11 of SP 15.13330.2012 «Stone and reinforced stone structures». Thus, it is not practical to use polyurethane foam glue in masonry made of cellular concrete blocks of autoclave hardening class B1.5 for compressive strength.

– The nature of the destruction of samples made on polyurethane foam adhesives (destruction occurred on the body of the concrete), indicates the solidity of the masonry (Figure 6).

– The nature of the destruction of samples and the analysis of test results allows us to conclude that the resistance to axial tension in the non-tied cross-section (normal adhesion) of masonry depends on the strength of the axial tension of the material from which the block is made, and not on the compressive strength of the masonry (binder) solution used, as indicated in table 11 of SP 15.13330.2012 «Stone and reinforced stone structures». This factor must be taken into account when calculating masonry from cellular concrete blocks of autoclave hardening on polyurethane foam compositions.
References

[1] Polyakov S V 1959 Clutch in masonry (Moscow: Stroiizdat) 84
[2] Izmailov Yu V and Mitin A R 1971 Clutch in masonry of lightweight concrete blocks (Kishinev: TsK KP Moldavii) 89
[3] Konovodchenko V I and other 1976 Effective ways to increase adhesion in the masonry of silicate brick J. Construction and architecture of Uzbekistan 5 11-14
[4] Derkach V N 2012 Strength of normal adhesion of cement mortars in masonry J. Engineering and Construction Journal 7 6-13
[5] Gorshkov A S and Vatin N I 2013 Properties of wall constructions from cellular concrete products of autoclave hardening on polyurethane glue J. Engineering and Construction Journal 5 5-18
[6] Gorshkov A S, Mishin V E and Vatin N I 2014 Increasing the thermal uniformity of walls made of cellular concrete products by using polyurethane glue in masonry J. Building Materials 5 57-64
[7] Glumov A 2014 Laying on polyurethane structures: how to eliminate cold bridges J. Construction materials, equipment, technologies of the XXI century 4 30-31
[8] Granovsky A V and Dzhamuev B K 2011 Tests of wall structures made of cellular concrete blocks for seismic effects Modern production of autoclaved aerated concrete: Collection of reports of a scientific and practical conference (St. Petersburg) 104-108
[9] Granovsky A V, Dzhamuev B K, Vishnevsky A A and Grinfeld G I 2015 Experimental determination of normal and tangential adhesion of masonry from aerated concrete blocks of autoclave hardening on various adhesive compositions J. Building Materials 8 22-25
[10] Greenfeld G I and Kharchenko A P 2013 Comparative tests of masonry fragments from autoclaved aerated concrete with various designs of masonry seam J. Housing construction 11 30-34
[11] Derkach V N 2017 Strength and deformability of stone masonry made of cellular concrete blocks of autoclave hardening with polyurethane joints. Part 1. Strength and deformability under compression J. Building Materials 5 29-32
[12] Derkach V N 2017 Strength and deformability of stone masonry made of cellular concrete blocks of autoclave hardening with polyurethane joints. Part 2. Bending tensile strength J. Building Materials 7 30-33
[13] Derkach V N 2017 Strength and deformability of stone masonry made of cellular concrete blocks of autoclave hardening with polyurethane joints. Part 3. Strength and deformability at shear J. Building Materials 8 32-35
[14] Lu S, Kasa M and Habian E 2010 Innovation on masonry glued with on-site PU-adhesive 8th International Masonry Conference 2010 (Dresden) 224-228
[15] Graubohm M and Brameshuber W 2010 Investigation on the gluing of masonry units with polyurethane adhesive 8th International Masonry Conference (Dresden) 371-376
[16] Lazar I I and Dzhamuev B K 2019 The increase in the monolithcity of masonry walls made of cellular concrete blocks when using polymer-cement mortars in joints The collection of materials of the seminar for young scientists of the XXII International scientific conference «Construction - the formation of the living environment» (Tashkent) 333-335
[17] Dzhamuev B K 2019 Polymer cement mortars in masonry of cellular concrete blocks of autoclave hardening as one of the methods of increasing the normal adhesion J. Housing construction 11 46-50
[18] Dzhamuev B K 2019 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 International Conference «Modelling and Methods of Structural Analysis» (Moscow) 12 1425