Strengthening of brickwork composite reinforcement cage

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Abstract. The article discusses methods of strengthening brickwork using composite materials. These techniques have not been widely used in Uzbekistan due to the lack of a regulatory framework that would regulate their use. The article analyzes the existing methods of reinforcement of brickwork, and also suggests a method for calculating these methods of reinforcement with conclusions and recommendations based on it. The purpose of the work was to review the technology and analyze the advantages and disadvantages of each of the methods that should be used when choosing solutions to strengthen masonry. In conclusion, the need for further tests was confirmed in order to confirm the theoretical conclusions with practical results.

1 Introduction

Many buildings in Uzbekistan are made of brick. Brick as a building material combines such qualities as: strength, durability, environmental friendliness, low thermal conductivity, architectural expressiveness and many others. Uneven precipitation of soils, the effects of atmospheric precipitation, temperature differences, shortcomings and errors of design solutions, non–compliance with technological and operational standards and regulations - all this accelerates the process of destruction of masonry. Timely repair and reinforcement of the building's load-bearing structures keep it in working condition. The issue of ensuring the durability of brickwork has always been relevant [5]. The purpose of the work is a technical and economic analysis of the reinforcement of brickwork with composite materials of building structures of buildings and structures, as well as a description of the general technology with an analysis of the advantages, disadvantages and effectiveness of each of the methods that will serve as recommendations when choosing works to strengthen brickwork. The main methods of strengthening brick structures are:
- strengthening with clips,
-strengthening with strained belts made of steel,
- strengthening with composite materials.

The first study of the strength of masonry reinforced with a cage was carried out in 1936 by V.A. Kameiko. Brick pillars with a cross section of 51×51 sm and a height of 2.5 m were

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included in a frame of vertical corners placed on mortar at the corners of the pillar. Corners every 45sm in height were connected by welding with strips of 50x10 mm strip steel; vertical force was not transmitted directly to the corners from the press. This type of cage increased the strength of the masonry by 77% compared to the original strength.

In 1944 -1945 M.Ya. Pildish tested brick pillars included in cages made of plastered steel mesh and brick on edge with steel clamps laid in horizontal seams, as well as reinforced with reinforced concrete and steel cages. A special series of samples, reinforced with clips, were tested at various eccentricities of application of the longitudinal force.

In the work of V.A. Kameiko and R.N. Kvitnitsky, tests were carried out on brick pillars with a cross-section of 38x51sm and a percentage of masonry reinforcement of 0.3 and 0.6% that were previously destroyed and then included in a reinforced plaster casing. Based on the test results, it was established that the use of a plaster clip led to an increase in the strength of the masonry as a percentage of the reference sample by 4.3% with a percentage of masonry reinforcement of 0.3% and by 12.7% with a percentage of reinforcement of 0.6% [1].

Another method of strengthening structures that is widely used today is to inject a special solution under pressure into damaged masonry (wall) or reinforced concrete walls with cracks.

Simultaneous strengthening of structures with a steel cage and injection of mortar into the cracks of damaged masonry is recommended in cases where installing only a cage does not ensure the solidity of the masonry, and injection alone does not ensure the required strength of the masonry. The combined use of these methods helps to increase the load-bearing capacity and restore the solidity of the structure.

The work of Malganov A.I., Plevkov V.S. and Polishchuk A.I. discusses ways to strengthen brick walls by removing the load from them and placing steel support posts under the lintel. The authors proposed a scheme in which in racks made of corners with welded strips, the thickness of the strips increases from the ends of the racks to the middle. When constructing composite racks from corners of different sections, the center of gravity of subsequent sections is shifted relative to the previous ones towards the pier [3].

In the work of Ishchuk M.K., Frolova I.G. and Ishchuk E.M., the authors conducted studies of the strength and deformability of masonry reinforced with drill-injection studs, from which it was established that the bearing capacity of masonry reinforced with restressed studs is 1.5÷2 times higher than masonry with mesh reinforcement of the same section [4].

However, the existing method of strengthening brick walls with the help of conventional steel bands is more effective and less labour-intensive compared to that proposed in the work of Ishchuk M.K., Frolova I.G. and Ishchuk E.M. since it does not depend on the amount of adhesion of the reinforcing bars through the injection composition with elements of masonry (brick, mortar) and the strength of the mortar, and also does not require the installation of a large number of separate spacer plates along the outer contour of the brick walls.

2 Materials and methods

National practice distinguishes the following traditional methods of strengthening brickwork:
- the use of steel clips, clamps, etc.;
- the device of the core;
- injection of special solutions;
- partial or complete replacement of masonry elements.

Despite the effectiveness of increasing the strength characteristics of brickwork by traditional methods, there is a change in the external configuration of the reinforced object. The method of injecting the solution is suitable for minor damage. In the case of replacing the old masonry with a new one, the reinforcement is accompanied by additional labour-intensive work on the unloading device [2-11].

Alternative methods of strengthening stone structures:

1. Strengthening of brickwork with composite materials

Description of elements and technology for strengthening prototypes: Prototypes of brick pillars with a cross section of 380×510mm at a height of 1183mm were manufactured and tested in the laboratory of the Fergana Polytechnic Institute. Figure 1 shows the diagrams of experimental samples of brick pillars.

To determine the value of tensile strength (average tensile strength) and the calculated compressive strength of the masonry, compression and bending tests were carried out on 6÷10 control samples of bricks selected from each batch supplied by the brick factory, and mortar cubes measuring 7.07×7.07×7.07sm, manufactured in the process of laying experimental samples of brick pillars [5][10].

Determination of the load-bearing capacity of masonry reinforced with plaster casing.

The following material and dimensions were adopted for this research work;

Brick brand - M100.
M solution – M75.
Column cross-section b×h = 510x380 mm.
Column height = 1183 mm.
Coefficient m_g=1.
Coefficient m_b=1.

The characteristics of the plaster casing were assigned:

Cement-sand mortar M75. Layer thickness 50 mm. Reinforcing mesh made of glass composite with a diameter of Ø4 mm (A_s= 10.03 mm^2). R_s = 330MPa. Grid cell – 100×100 mm.

$$\lambda = \frac{H_{colh}}{h_{col}} = \frac{1183}{380} = 3.11 \tag{1}$$

$$\varphi = 1$$

Calculated masonry resistance

$$R = 2.2MPa$$

Percentage of reinforcement

$$\mu = \frac{2A_s\left(h_c + b_c\right)}{h_c \times b_c \times S} = \frac{2\times 10.03\left(51+38\right)}{51\times 38\times 5} = 0.18\% \tag{2}$$

Coefficients

$$\psi = 1, \eta = 1$$

Masonry without damage

$$m_k = 1$$

Cross sectional area of the masonry

$$A = b_c \times h_c = 510\times 380 = 193800mm^2 \tag{3}$$

We determine the load-bearing capacity of masonry reinforced with plaster casing

$$N = \psi\varphi\left[\left(m_g m_b R + \eta\frac{2.8\mu}{1+2\mu}\times\frac{R_s}{100}\right)A\right]$$
$$= 1\times1\left[\left(1\times1\times2.2 + 1\times\frac{2.8\times0.18}{1+2\times0.18}\times\frac{330}{100}\right)\times193800\right] = 663366N \quad (4)$$

Thus, the bearing capacity of brick pillars reinforced with composite reinforcement is 663kN.

Tests of control brick samples for compression and bending were carried out in accordance with the requirements of GOST 530-2007 “Ceramic bricks and stones. General technical conditions”. The strength of the mortar in the joints of the brickwork of the prototypes was determined in accordance with the instructions of GOST 5802-86 “Building mortars. Test methods”. To strengthen the brick pillars, RGC glass-composite reinforcement, developed by local manufacturers, was used. The glass composite reinforcement used in the experiment has the following characteristics (properties of the original fiber):

- elastic modulus- 55 000 MPa
- tensile strength-1200 MPa
- elongation at break-2.2%
- durability- predicted durability of at least 80 years

Experimental samples of brick pillars were tested in the structural testing laboratory of the Fergana Polytechnic Institute according to the methodology developed and used at the institute. The test diagram is shown in Figure 2 [6].

The adopted scheme for fastening the column at the upper and lower levels corresponded to the hinged connection of the structure with the press supports. Figure 3 shows a diagram of the arrangement of measuring instruments for measuring the magnitude of vertical and horizontal deformations of the masonry during its compression. Deformation measurements were carried out using dial indicators with a division value of 0.01 mm.

a) b) c)

Fig. 1. View of experimental samples of brick pillars. Reference sample (a, b) and prototype (c)

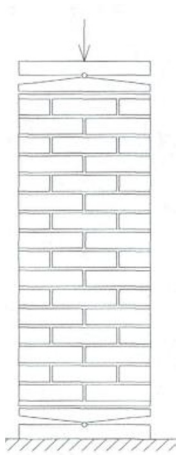

Fig. 2. Test scheme for brick pillars.

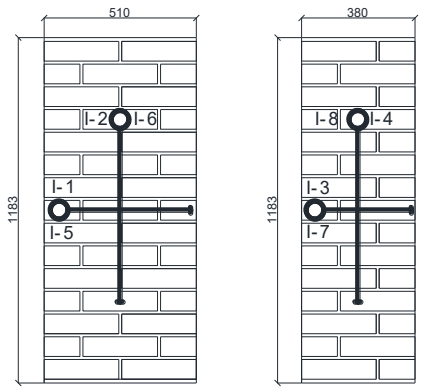

Fig. 3. Indicator layout diagram

The load on the prototype brick pillars was applied in steps of approximately 10% of the expected value of the breaking load. The intervals between loading steps were 8÷10 minutes. At the beginning and at the end of each loading stage, masonry deformations were measured [7].

3 Results and discussion

Based on the analysis of the test results of brick pillars reinforced with glass-composite reinforcement samples, and comparing them with the test results of reference (non-reinforced) prototypes, the following was established.

1. The nature of the deformations of the brickwork of the reference samples allows us to state that the loading of the reference samples was close to central compression. Herewith:

- the values of the eccentricities of the load application relative to the longitudinal axis - "y" (according to the thickness of the sample h = 38sm) changed in the test samples in the range from 0.46 to 1.10sm;
- the first hairline vertical cracks appeared in the middle part along the length (b=51sm) of brick pillars under loads of (0.8÷0.85) x $N_{failure}$;
- the destruction of the brickwork of the reference samples occurred at loads equal to 429.2kN, 424.3kN and 431.0kN. At the same time, the average value of the temporary compressive strength of the brick masonry pillars corresponded to Ru = 2.26 MPa with the calculated compressive resistance of the masonry = l.3 MPa (brick grade M100, mortar – M75).
- the destruction of the brickwork of the samples occurred at loads equal to 680, 674,66 681kN. At the same time, the temporary compressive strength of the brickwork of the pillars was 3.51, 3.48, 3.51 MPa. The coefficient K varied in the range from 3.47 to 4.17 with a normalized value of K=2. Those. with the reinforcement scheme adopted in the samples, the strength of the masonry increased in comparison with the reference samples by more than 2 times;
- in the reference (unstrengthen) test samples under loads close to destructive ($N \approx 350kN$), the values of the maximum transverse deformations of the masonry averaged $\varepsilon = (0.5 \div 1.5) \times 10^{-3}$;
- under loads close to destructive, in the reference samples, due to large transverse deformations of the masonry, vertical cracks formed in the section averaged over the height

of the sample, with the division of the sample masonry into separate columns with their subsequent crushing [8-9];
- at the moment of destruction of the prototypes, the brick was crushed and split (due to large transverse deformations) along the contour of the pillar. At the same time, the formation of vertical cracks in the samples was not detected; (Table 1)

Table 1. Test results of samples

Sample series	**i**	**Sample cross-section size b×l (cm)**	**Brand of brick/mortar**	**Experimental breaking load Nbrek (kN)**	**Temporary compressive resistance of masonry** $R_u = N_{brek} / A$	**Eccentricities of load application relative to the transverse and longitudinal axes** e_x/e_y (sm)	$\psi = 1 - \frac{2e_y}{h}$	ω	$R_{cl} = \frac{R_u \cdot k}{\omega \cdot \psi}$ **(MPa)**	**Rrelative strength of masonry (%)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**		**9**	**10**
Reference	1	38x51	$\frac{M75}{M50}$	429.20	2.21	0.77/0.49	0.974	1.01	2.25	100
	2			424.30	2.19	1.53/1.1	0.942	1.02	2.27	
	3			431.00	2.22	0.69/0.46	0.975	1.01	2.25	
Reinforced	1	38x51	$\frac{M75}{M50}$	680.00	3.51	1.80/1.96	0.967	1.05	3.79	181
	2			674.66	3.48	2.14/2.60	0.956	1.07	4.89	
	3			681.00	3.51	3.35/1.68	0.972	1.04	3.67	

4 Conclusion

Based on the analysis of the results of experimental and theoretical studies of the strength and deformability of brick pillars and piers reinforced with composite fiberglass reinforcement, the following was established.
1. The proposed design solution for strengthening brick pillars using composite reinforcement makes it possible to increase the strength of brickwork, depending on the requirements of the project and the location of the composite reinforcement along the height of the brick pillar by 1.3÷1.8 times.
2. The nature of the destruction of samples of brick pillars reinforced with fiberglass composite reinforcement, with different locations along the height of the sample, corresponds to the classical pattern of destruction of brickwork reinforced with reinforcing mesh or clips, identified in the studies of various authors.
3. The use of glass composite reinforcements makes it possible to create a cage and, as a consequence, increase the strength of the masonry operating under volumetric stress conditions.
4. Analysis of the experimental results and comparison of the indicators of the relative strength values of masonry (Fig.1), reinforced with external fiberglass reinforcement, with masonry reinforced with reinforcing mesh, with their identical location along the height of the samples, allows us to conclude that the proposed in the article is quite correct describes the behavior of brick pillars reinforced with fiberglass reinforcement under centrally and eccentrically applied loads, and can be used in design practice.

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