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EVALUATION OF THE EFFECTIVENESS OF STRENGTHENING BRICK MASONRY WITH GLASS-FIBER COMPOSITE REINFORCEMENT BASED ON EXPERIMENTAL TESTS

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ABSTRACT

The article examines methods for strengthening brick masonry using composite materials. These methods have not become widespread in Uzbekistan because there is no regulatory framework governing their use. The article analyzes existing methods for reinforcing brick masonry and proposes a calculation methodology for these strengthening methods, with conclusions and recommendations based on the results. The aim of the study was to consider the technology and analyze the advantages and disadvantages of each method that should be used when selecting solutions for strengthening masonry. In conclusion, the need for further tests was confirmed in order to validate theoretical findings with practical results.

KEYWORDS

Masonry, stress state, elastoplastic body, moment, transverse force, reinforcement, cement mortars, masonry strength, calculation scheme.

Introduction

Many buildings in Uzbekistan are constructed of brick. Brick as a building material combines such qualities as strength, durability, environmental friendliness, low thermal conductivity, architectural expressiveness and many others. Uneven ground settlement, the impact of atmospheric precipitation, temperature fluctuations, deficiencies and errors in design solutions, and non-compliance with technological and operational standards and rules accelerate the deterioration of masonry. Timely repair and strengthening of load-bearing structures keep the building in working condition. The issue of ensuring the durability of brick masonry has always been relevant. The purpose of this work is to perform a technical and economic analysis of strengthening brick masonry in building structures using composite materials, as well as to describe the general technology with an analysis of the advantages, disadvantages and efficiency of each method. These findings can serve as recommendations when selecting strengthening works for brick masonry.

2. Methods

In practice, the following traditional methods of strengthening brick masonry are distinguished:
- use of steel staples, clamps, and similar elements;
- installation of a core;
- injection of special mortars;
- partial or complete replacement of masonry elements.

Despite the effectiveness of traditional methods in improving the strength characteristics of brick masonry, they change the external configuration of the strengthened object. The mortar-injection method is suitable for minor damage. When old masonry is replaced with new masonry, strengthening is accompanied by additional labor-intensive operations related to unloading the structure [2][11].

Alternative methods for strengthening masonry structures:

1. Strengthening brick masonry with composite materials

In the laboratory of Fergana Polytechnic Institute, brick column specimens with a cross-section of 380×510 mm and a height of 1183 mm were prepared and tested. Figure 1 presents the schemes of the experimental brick column specimens.

To determine the ultimate strength value (average ultimate strength) and the design compressive strength of masonry, compression and bending tests were conducted on 6-10 control brick specimens selected from each batch supplied by the brick plant, and on mortar cubes measuring 7.07×7.07×7.07 cm, manufactured during the construction of the experimental brick column specimens [5][10].

Determination of the load-bearing capacity of masonry strengthened with cement-sand mortar.

The following materials and dimensions were adopted for this research work:

Brick grade - M100; mortar grade - M7.5; column cross-section b×h = 510x380 mm; column height = 1183 mm; coefficient $m_g = 1$; coefficient $m_b = 1$.

The following characteristics were assigned to the mortar jacket:

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

$$\lambda = \frac{H_{кол}}{h_{кол}} = \frac{1183}{380} = 3.11 \qquad (1)$$

$$\varphi = 1$$

Design resistance of masonry

$$R = 2.2MPa$$

Reinforcement percentage

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

Coefficients

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

Masonry without damage

$$m_k = 1$$

Cross-sectional area of masonry

$$A = b_к \times h_к = 510\times 380 = 193800mm^2 \qquad (3)$$

Determination of the load-bearing capacity of masonry reinforced with glass-composite reinforcement and mortar

$$N = \psi\varphi\left[\left(m_g m_b R + \eta\frac{2.8\mu}{1+2\mu}\times\frac{R_s}{100}\right)A\right]$$

$$= 1\times1\left[\left(1\times1\times2.2 + 1\times\frac{2.8\times0.18}{1+2\times0.18}\times\frac{330}{100}\right)\times193800\right] = 663366N \quad (4)$$

Thus, the load-bearing capacity of brick columns strengthened with composite reinforcement is 663 kN.

a) b) c)

Fig. 1. General view of experimental brick column specimens. Reference specimens (a, b) and strengthened specimen/prototype (c)

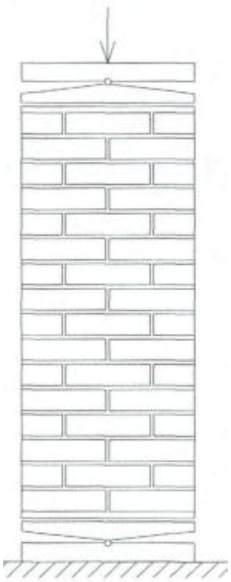

Fig. 2. Testing scheme for brick columns.

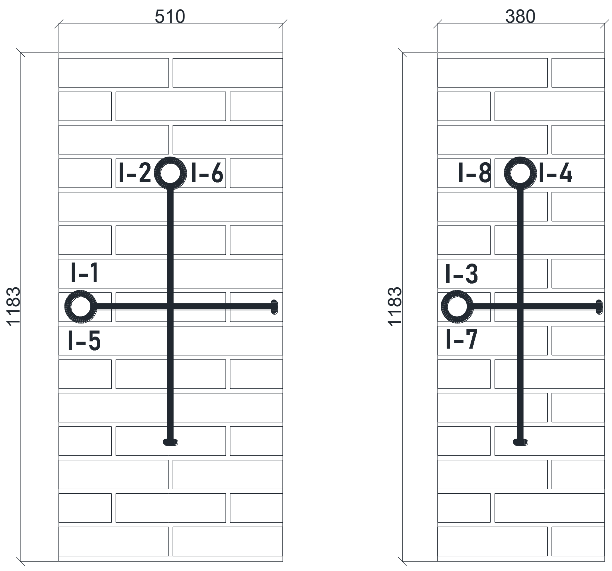

Fig. 3. Indicator arrangement scheme

The experimental brick column specimens were tested in the structural testing laboratory of Fergana Polytechnic Institute according to the methodology developed and applied at the institute. The testing scheme is presented in Figure 2 [6].

The adopted support scheme of the column at the upper and lower levels corresponded to a hinged connection of the structure with the press supports. Figure 3 shows the arrangement of measuring devices used to measure vertical and horizontal deformations of the masonry during compression. Deformation measurements were performed using dial indicators with a scale division of 0.01 mm.

The load on the brick column prototypes was applied in increments of approximately 10% of the expected failure load. The intervals between loading stages 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 test results for brick columns strengthened with glass-composite reinforcement and their comparison with the results for reference (unstrengthened) specimens, the following was established.

1. The deformation pattern of the reference brick masonry specimens indicates that the loading of the reference specimens was close to central compression. At the same time:

- the eccentricities of load application relative to the longitudinal axis "y" (along the specimen thickness h = 38 cm) varied in the tested specimens from 0.46 to 1.10 cm;
- at (0.8-0.85) x Nfailure, the first hairline vertical cracks appeared;
- failure of the reference brick masonry specimens occurred at loads of 429.2 kN, 424.3 kN and 431.0 kN. At the same time, the average temporary compressive strength of the brick masonry columns was Ru = 2.26 MPa, with the design compressive resistance of masonry equal to 1.3 MPa (brick grade M100, mortar M7.5).
- failure of the strengthened masonry specimens occurred at loads of 680.0 kN, 674.66 kN and 681.0 kN. The temporary compressive strength of the masonry columns was 3.51, 3.48 and 3.51 MPa, respectively. The coefficient K varied from 3.47 to 4.17, with the normalized value K = 2. Thus, with the strengthening scheme adopted for the specimens, the masonry strength increased by more than 1.5 times compared with the reference specimens;
- in the reference (unstrengthened) test specimens, under loads close to failure ($N \approx 350 kN$) the averaged values of maximum transverse deformations of the masonry were $\varepsilon = (0.5 \div 1.5) \times 10^{-3}$;
- under loads close to failure, vertical cracks formed in the control specimens due to large transverse deformations of the masonry in the section averaged over the height of the specimen, followed by separation of the masonry specimen into individual columns and their subsequent crushing [8][9];
- at the moment of failure of the prototypes, the bricks were crushed and split along the contour of the column due to large transverse deformations. At the same time, no vertical cracks were detected in the specimens;

Test results of the specimens

Specimen series	i	Cross-sectional dimensions of specimen bxl (cm)	Brick/mortar grade	Experimental failure load Nf (kN)	Temporary compressive strength of masonry $R_u = N_{brek} / A$	Load application eccentricities relative to transverse and longitudinal axes ex/ey (cm)	$\psi = 1 - \frac{2e_y}{h}$	ω	$R_{cl} = \frac{R_u \cdot k}{\omega \cdot \psi}$ (MPa)	Relative masonry strength R (%)
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	1.53/1.10	0.942	1.02	2.27	
	3			431.00	2.22	0.69/0.46	0.975	1.01	2.25	
Strengthened	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. Conclusions

Based on the analysis of experimental and theoretical research results on the strength and deformability of brick columns and piers strengthened with glass-fiber composite reinforcement, the following was established.

1. The proposed structural solution for strengthening brick columns using composite reinforcement makes it possible to increase the strength of brick masonry by 1.3-1.8 times, depending on project requirements and on the arrangement of composite reinforcement along the height of the brick column.

2. The failure pattern of brick column specimens strengthened with glass-fiber composite reinforcement with different arrangements along the specimen height corresponds to the classical failure pattern of brick masonry strengthened with a composite mesh or jackets, as identified in studies by various authors.

3. The use of glass-composite reinforcement makes it possible to create a reinforcing frame and, as a result, to increase the strength of masonry working under a three-dimensional stress state.

4. The analysis of experimental results and comparison of the relative strength indicators of masonry reinforced with external glass-fiber reinforcement with masonry reinforced by a reinforcing mesh, under the same arrangement along the height of the specimens, allows the conclusion that the approach proposed in the article adequately describes the behavior of brick columns reinforced with glass-fiber reinforcement under centrally and eccentrically applied loads and can be used in design practice.

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