DOI: 10.33942/sit1820 **УДК 692.214**

ЭКСПЕРИМЕНТТИК ИЗИЛДӨӨЛӨР ҮЛГҮЛӨРДҮ ДОЛБООРЛОР ЖЕТЕКЧИЛИК, КҮЧӨТҮЛГӨН КОМПОЗИЦИЯЛЫК МАТЕРИАЛДАРЫ НЕГИЗИНДЕ КӨМҮРТЕК БУЛА, ИШ-АРАКЕТИНЕ СТАТИКАЛЫК ЖҮКТӨМҮНӨ

Кульбаев Б.Б. [1], Шокбаров Е.М.[2], Темиралиулы Г.[3]

[1]*башкы директор, АО "КАЗАХСКИЙ ИЛИМИЙ-ИЗИЛДӨӨ ИНСТИТУТУ КУРУЛУШ ЖАНА АРХИТЕКТУРА", 050046, Алматы ш., Солодовникова көчөсү, 21,* bkulbayev@kazniisa.kz
[2]*башкаруучу директор, т.и.к.,* eshokbarov@kazniisa.kz
[3]*имараттардын жана курулмалардын жер титирөөгө туруктуулугу секторунун жетектөөчү инженери, магистр,* gtemiraliuly@kazniisa.kz

Аннотация. *Натыйжалар сунушталды эксперименттик изилдөөлөрдүн таасирин күчөтүү үлгүлөрүн таш кладки композитными материалдары негизинде көмүртек катмары болгон жөндөмдүүлүгү жана деформативность алдындагы иш-аракетинде статикалык жүктөмүнө. Таш кладка көтөрүү жөндөмдүүлүктүн өзгөрүшүнө күчөтүлгөн үлгүлөрдүн иш механизми жана таасири аныкталды. Курама материалдын катмарынын таасирин көтөрүү боюнча талдоо жүргүзүлгөн. Таш кладка күчөтүлгөн үлгүлөрдүн көтөрүмдүүлүк жөндөмдүүлүгүнүн жогорулашына жараша аныкталат.*

Негизги сөздөр: *Көмүртек буласы, композициялык материал күчөтүү композициялык материалдар үлгүлөрү жасалган таш, көмүртек тасма, көмүртек кездеме, көмүртек торчо, тышкы арматура, жөндөмдүүлүгү.*

ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ ОБРАЗЦОВ ИЗ КИРПИЧНОЙ КЛАДКИ, УСИЛЕННОЙ КОМПОЗИТНЫМИ МАТЕРИАЛАМИ НА ОСНОВЕ УГЛЕРОДНОГО ВОЛОКНА, НА ДЕЙСТВИЕ СТАТИЧЕСКОЙ НАГРУЗКИ

Кульбаев Б.Б. [1], Шокбаров Е.М.[2], Темиралиулы Г.[3]

[1]*генеральный директор, АО «КАЗАХСКИЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ СТРОИТЕЛЬСТВА И АРХИТЕКТУРЫ», 050046, г. Алматы, ул. Солодовникова, 21,* bkulbayev@kazniisa.kz
[2]*управляющий директор по производству, к.т.н.* eshokbarov@kazniisa.kz
[3]*ведущий инженер сектора сейсмостойкости зданий и сооружений, магистр,* gtemiraliuly@kazniisa.kz

Аннотация. *Представлены результаты экспериментальных исследований влияния усиления образцов каменной кладки композитными материалами на основе углеродных волокон на несущую способность и деформативность при действии статической нагрузки. Определены механизм работы усиленных образцов и влияние усиления на изменение несущей способности каменной кладки. Проведен анализ влияния количества слоев композитного материала на повышение несущей способности. Представлены зависимости определения повышения несущей способности усиленных образцов каменной кладки.*

Ключевые слова: *Углеродное волокно, композитный материал, усиление композитными материалами, образцы из каменной кладки, углеродная лента, углеродная ткань, углеродная сетка, внешнее армирование, несущая способность.*

EXPERIMENTAL STUDIES OF SAMPLES FROM BRICKWORK REINFORCED WITH CARBON FIBER-BASED COMPOSITE MATERIALS ON THE EFFECT OF STATIC LOAD

Kulbayev B.B. [1], Shokbarov Y.M.[2], Temiraliuly G.[3]

[1]*general manager, JSC «KAZAKH RESEARCH INSTITUTE OF CONSTRUCTION AND ARCHITECTURE», 050046, Almaty city, Solodovnikova Street 21, bkulbayev@kazniisa.kz*
[2]*managing director, c.t.s. eshokbarov@kazniisa.kz*
[3]*leading engineer of the earthquake resistance sector of buildings and structures, master of construction, gtemiraliuly@kazniisa.kz*

Annotation. *The results of experimental studies of the effect of reinforcement of masonry samples with composite materials based on carbon fibers on the load-bearing capacity and deformability under the action of static load are presented. The mechanism of operation of reinforced samples and the effect of reinforcement on the change in the load-bearing capacity of masonry are determined. The analysis of the influence of the number of layers of composite material on the increase in load-bearing capacity is carried out. The dependences of determining the increase in the load-bearing capacity of reinforced masonry samples are presented.*
Keywords: *Carbon fiber, composite material, reinforcement with composite materials, masonry samples, carbon tape, carbon fabric, carbon mesh, external reinforcement, load-bearing capacity.*

The purpose of this work is to conduct experimental and theoretical studies of masonry samples reinforced with carbon fiber-based composite materials under the action of static loads.

To achieve this goal, the following main tasks were solved:

-experimental studies of the physical and mechanical characteristics of the materials used in the manufacture of stone samples were carried out;

- the load-bearing capacity of masonry under different dressing systems is compared;

- an analysis of the effect on the load-bearing capacity of the adhesive between the reinforcement element and the surface of the masonry samples was carried out;

- a study of the load-bearing capacity of stone samples reinforced with carbon tapes and fabrics, quadroaxial fabrics and carbon meshes on the repair composition was carried out;

- the influence of the number of reinforcement layers on the load-bearing capacity of stone samples was evaluated;

- the existing dependence on the determination of the load-bearing capacity of masonry reinforced with composite materials based on carbon fiber was checked;

- a comparative analysis of the results obtained with the results of previously performed studies was carried out [1].

For experimental and theoretical studies, samples of masonry with dimensions of 1060x1060x250 mm were made. All samples were made of solid masonry with a chain dressing system, except for 2 samples, which were made with a five-row dressing system. At the same time, all seams, both horizontal and vertical, were completely filled with the solution. For masonry, a full-bodied brick of the M125 was used. As a masonry mortar, a ready - made dry mix was used- a cement-sand mortar of the M150.

The method of experimental studies is chosen by analogy with the work [1,5,6,7] where a static load was created in the power frame using a hand pump NRG-7020 and a hydraulic jack DG-50P150. The power frame was a metal box-shaped frame structure made of welded channels No. 16. The height of the structure is 4.10 m, width-1.20 m. The load was perceived by 4 threaded studs M36 * 2000, passed through pipes with a wall thickness of 10 mm. The pipes are welded to the power frame and the distribution beam with the help of shapes. The distribution beam was fixed with DIN934 galvanized M36 nuts (Fig. 1).

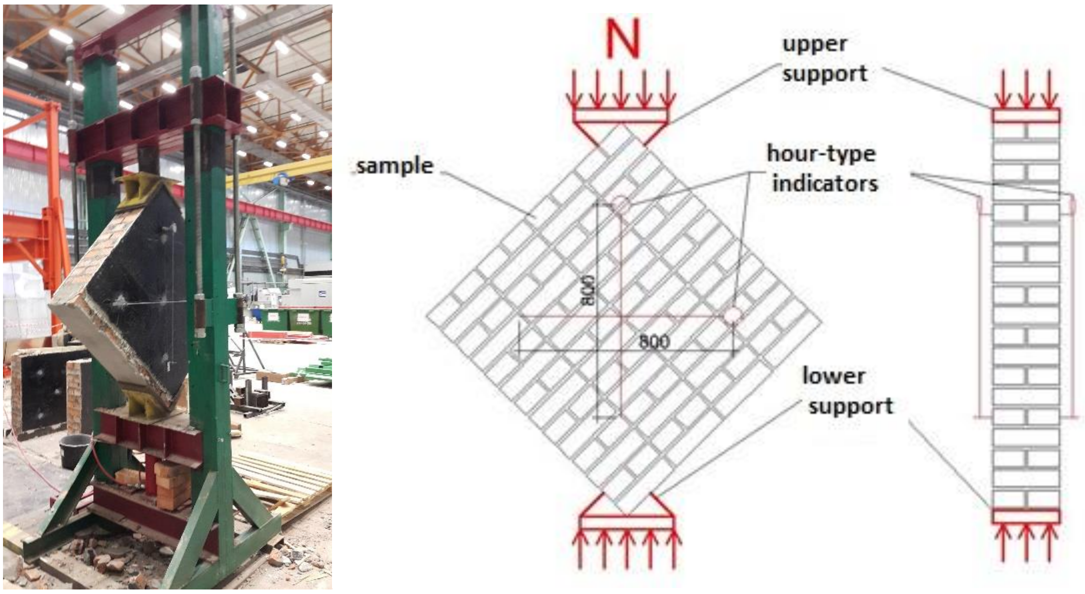

Fig. 1. General view of the experimental sample and the power frame. Sample loading scheme

For the tests, samples were made from masonry of 8 series, 4 pieces for the reference series and 3 pieces for the reinforced series. Carbon tapes, fabrics, and meshes were applied to the masonry surface using the technology described in [2,3,4]. The total number of experimental samples of masonry is 25 pieces.:

ME series-reference samples without reinforcement in the amount of 4 pieces; 2 samples are made with a chain dressing system, 2 samples from masonry with a multi-row dressing system;

MR-2 series-samples reinforced with carbon unidirectional tape FibARM Tape 230/300 with a width of 300 mm, glued in the middle of the sample on one side in three layers using a two-component epoxy binder FibARM Resin 230+;

MR-3 series-samples reinforced with carbon unidirectional tape FibARM Tape 530/300 with a width of 300 mm, glued in the middle part of the sample, on both sides in two layers using a two-component epoxy binder FibARM Resin 530+;

MR-4 series-samples reinforced in height with three carbon unidirectional tapes FibARM Tape 230/300 with a width of 300 mm, glued on one side in three layers using a two-component epoxy binder FibARM Resin 230+. The distance between the belts is 270 – 300 mm.;

MR-5 series-samples reinforced on one side with FibARM Grid 600/1000 carbon mesh with impregnation, 1000 mm wide on the FibARM Repair FS repair compound;

MR-6 series-samples reinforced with a 1000 mm wide quadroaxial fabric glued on one side with a two-component epoxy binder FibARM Resin 530+;

MR-7 series-samples reinforced on both sides with FibARM Tape 450/600 carbon fabric with a width of 1000 mm, glued with a two-component epoxy binder FibARM Resin 530+ with four carbon fiber Anchor bundles with a length of 560 mm, installed along the diagonals;

MR-8 series-samples reinforced on both sides with a quadroaxial fabric 1000 mm wide, glued with a two-component epoxy binder FibARM Resin 530+ with four carbon fiber Anchor bundles 560 mm long, installed along the diagonals.

Experimental studies were carried out as a continuation of previously performed work [1]. In this regard, to analyze the effect of reinforcement with a carbon fiber-based composite material on the load-bearing capacity of masonry, the results of these and previous tests were used. The test methods in both studies were completely similar. The differences were only in the number of reinforcement layers, the reinforcement material, and the way the carbon fiber was applied to the masonry.

During the tests, the load on the samples was applied in stages of 10% of the destructive load at the initial stage of loading and 5% at the stage close to destruction. The force was maintained at each stage for 2 minutes, followed by fixing the deformations.

The analysis of the results of the conducted and previously performed tests was carried out by the value of the shear force Q, defined as the projection of the destructive vertical load on the face of the sample.

The destruction of the samples of the ME series occurred brittle, along the bandaged section of the masonry along the compressed diagonal with the formation of a single crack, i.e., when the masonry reached the limit values for the main tensile stresses.

Analysis of the test results showed that the load-bearing capacity of masonry, when reinforced with carbon fiber, increases from 14.1% to 73.2%. When using the conversion factor for the work [1], the increase in the load-bearing capacity for reinforced samples was from 27.2% to 70.4%

As a result of the experiment, it was revealed that the destruction of all reinforced samples occurred similarly to the reference samples brittle, almost instantly after reaching the maximum load.

To determine the theoretical value of the load-bearing capacity of samples reinforced with a composite material based on carbon fiber, it is proposed to use the physical characteristic k, which takes into account the strength characteristics of the carbon fiber, the reinforcement area relative to the total surface area of the structure, the width, thickness and number of layers:

$$k = \frac{A_{a_i}}{A_k} \cdot b_{fib} \cdot \delta_{fib} \cdot R_{fib} \cdot n, \text{ [dimensionless value]}, \quad (1)$$

where: A_{a_i} – application area (reinforcement) of composite material, m^2;

A_k – surface area of masonry, m^2;

b_{fib} – the width of the carbon fiber in the calculated section of the masonry, m;

δ_{fib} – single layer tape thickness, m;

R_{fib} – average value of the carbon fiber tensile strength, Pa;

n – number of carbon fiber layers.

According to the test results [8], graphical dependences of the change in the strength of masonry on the values of the physical characteristic k were constructed (Fig. 5). It was found that the different value of the increase in the load-bearing capacity is primarily due to differences in the technology of bonding composite fiber. The FibARM Repair FS repair compound was used as the leveling compound for these tests [2], while the leveling layer between the masonry and the composite material was not used in the work [1].

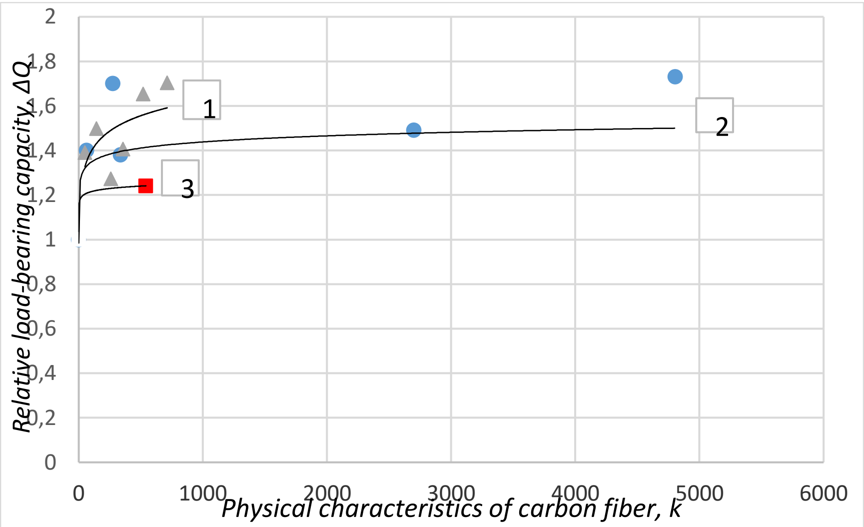

Fig. 5. Dependence of the relative load-bearing capacity on the physical characteristick:1- for testing purposes [1]; 2- for samples of the MR-2 - MR-4 and MR-6 - MR-8 series; 3- for samples of the MR -5.

The comparison of the test results with the proposed dependencies ranges from 10% to 40% in the direction of the load-bearing capacity margin.

Conclusions:

1. Reference samples made of solid masonry with a chain dressing system and samples made of masonry with a multi-row dressing system collapsed under almost the same load;

2. The use of the external reinforcement system based on carbon fiber "FibARM" to strengthen the masonry leads to an increase in the load-bearing capacity from 14% to 73%;

3. With the technology of applying the adhesive (binder) directly to the masonry, the adhesion of the composite material to the surface of the masonry is higher than with the technology using the levelling compound FibARM Repair FS. At the same time, the load-bearing capacity of the reinforced samples increases to 20%;

4 In the case of using 2 or 3 layers of composite material for strengthening masonry, it is proposed to introduce correction factors for the number of layers equal to 0.2 and 0.1, respectively, when determining the physical characteristic k;

5. The proposed analytical dependences for determining the shear force Q, taking into account the physical characteristic k, which takes into account the strength characteristics of carbon fiber, the reinforcement area, relative to the total surface area of the structure, the width, thickness and number of layers, with sufficient accuracy for practical calculations, allow us to determine the increase in the load-bearing capacity of masonry due to the use of an external reinforcement system based on carbon fiber.

BIBLIOGRAPHY:

*1. **Тонких, Г.П.** Экспериментальные исследования сейсмоусиления каменной кладки системой внешнего армирования на основе углеволокна / Г.П Тонких, О.В. Кабанцев, А.В. Грановский, О.А Симаков // Вестник ТГАСУ. - 2014. - № 6. - С. 57-69.*

2. Официальный интернет сайт компании ХК «Композит» - http://www.hccomposite.com/.

*3. **ТУ 2257-047-61664530–2014.** «Эпоксидное двухкомпонентное связующее FibArm Resin 230+ для пропитки систем внешнего армирования FibArm», ЗАО «Препрег-СКМ».*

*4. **ТУ 2257-048-61664530–2014.** «Эпоксидное двухкомпонентное связующее FibArm Resin 530+ для пропитки систем внешнего армирования FibArm», ЗАО «Препрег-СКМ».*

*5. **Тонких, Г.П.** Экспериментальные исследования несущей способности каменной кладки при главных нагрузках / Г.П. Тонких, О.В. Кабанцев, В.В. Кошаев // Сейсмостойкое строительство. Безопасность сооружений. – 2007. – № 6. - С. 26–31.*

*6. **Тонких, Г.П.** Экспериментальные исследования сейсмоусиления каменной кладки наружными бетонными аппликациями / Г.П. Тонких, О.В. Кабанцев, О.А. Симаков, С.М. Баев // Сейсмостойкое строительство. Безопасность сооружений. – 2011 – № 2. - С. 35–41.*

*7. **О.В. Кабанцев, Г.П. Тонких [и др.]** Пособие по оценке сейсмостойкости и сейсмоусилению общевойсковых зданий с несущими стенами из каменной кладки – Москва, 26 ЦНИИ МО РФ, 2002.*

*8. **Г.П. Тонких, Г. Темиралиулы** Итоговый отчет по результатам испытаний каменной кладки, усиленной композитными материалами на основе углеродного волокна при действии статических нагрузок – М. : НИУ МГСУ, 2016.*