Алдекеева Динара Танашбековна, к.т.н., ассоциированный профессор, Казахская академия транспорта и коммуникаций имени М. Тынышаева, г.Алматы, Казахстан, aldekeeva69@mail.ru.

Жуандык Айзат Мерекеқызы, магистрант МН-ТС-19, Казахская академия транспорта и коммуникаций имени М. Тынышаева, г.Алматы, Казахстан, aizanay@mail.ru.

ҚАЗАҚСТАННЫҢ АВТОМОБИЛЬ ЖОЛДАРЫН ҚАР ҚҰРСАУЫНАҢ ҚОРҒАУ ЖӨНІҢДЕГІ ТИІМДІ ШАРАЛАР

Бондарь Иван Сергеевич, т. г. к., сениор-лектор, М. Тынышбаев атындағы Қазақ көлік және коммуникациялар академиясы, Алматы, Қазақстан, ivan_sergeevich_08@mail.ru.

Алдекеева Динара Танашбековна, т. г. к., кауымдастырылған профессор, М. Тынышаев атындағы Қазақ көлік және коммуникациялар академиясы, Алматы, Қазақстан, aldekeeva69@mail.ru.

Жуандык Айзат Мерекеқызы, МН-ТС-19 магистранты, М. Тынышаев атындағы Қазақ көлік және коммуникациялар академиясы, Алматы, Қазақстан, aizanay@mail.ru.

Аннотация. Бұл мақалада Қазақстан аумағын қар көшкіні жағдайы бойынша аудандастыру қарастырылған. Қар қорғау құралдары келтірілген. Біздің еліміздің көлік магистральдарындағы қармен күрес негізінен қарды жинау немесе оны жолға жақын жолақта ұстау арқылы жүзеге асырылады. Барлық қардан қорғайтын екпелер қар ұстайтын және қар сіңіретін болып бөлінеді. Қазақстандағы автомобиль жолдарының бойындағы орман жолақтары негізінен оларды кар құрсауынаң қорғу ушін қасылды. Жолды қардан қорғаудан басқа, орман қорғау құрылыстары қарамды құмыр, борасындардан және желден қорғайды. Олар эстетикалық жұқтеме қатысты екетеді, флора мен фаунағының дамуына ықпал етеді. Әр түрлі ағаштар мен бұтальар болуы мүмкін.

Түйінді сөздер: қысқы күтіп ұстау, аудандастыру, қардан қорғау құралдары, қар ұстайтын дуалы, орман жолақтары, қарға төзімділік.

REINFORCEMENT OF REINFORCED CONCRETE STRUCTURES WITH COMPOSITE MATERIALS

Bondar Ivan, K. T. N., Senior Lecturer, Kazakh Academy of transport and Communications named after M. Tynyshpayev, Almaty, Kazakhstan, ivan_sergeevich_08@mail.ru.

Aldekeeva Dinara, K. T. N., associate professor, Kazakh Academy of transport and Communications named after M. Tynyshpayev, Almaty, Kazakhstan, aldekeeva69@mail.ru.

Salman Al Dulaimi Salman Dawood, K. T. N., associate professor, National Research Mordovian State University named after N. P. Ogarev, Saransk, Bolshevistskaya str., 68, Russian Federation, Republic of Mordovia, E-mail: salmoon-1985@mail.ru.

Kuatbayeva Tokzhan, Doctor of Technical Sciences, Professor of the Department "Construction and Building Materials", Satbayev University, Almaty, Kazakhstan, E-mail: tk-kuatbaeva1@mail.ru.

Abstract. Recently, in the Republic of Kazakhstan, as well as in other countries of the Asian region, it is becoming more and more urgent to strengthen the operated reinforced concrete structures with external reinforcement systems with carbon materials during the reconstruction of any engineering structures. In order to eliminate the consequences of concrete destruction and reinforcement corrosion as a result of long-term exposure to natural factors and aggressive environments, carbon fiber external reinforcement systems are widely used during the
operation of structures designed to repair and strengthen the load-bearing structures of artificial structures. External reinforcement is used to increase the seismic resistance, strength and reliability of the structures being built, as well as to increase the time between repairs. The repair system provides for the use of materials and technologies that ensure stopping and preventing further corrosion of reinforcement and concrete, reliable adhesion of repair compounds with old concrete, increased water resistance, frost resistance and chemical resistance. This article describes FibARM carbon materials that are used to strengthen columns and pylons, broadband reinforcement of slabs, beams, crossbars and structures with increased requirements for reinforcement joints, covering reinforcement of concrete with large-scale grid cracking. The main methods of strengthening the stretched and bent elements of building structures of artificial structures are considered, and the technology of work on strengthening the structures of artificial structures is also given.

**Keywords:** strengthening of constructions of artificial structures, a system of external reinforcement, composite materials, carbon fiber.

**Introduction**

Systems of external reinforcement with carbon strips for the reconstruction of any engineering structures are gaining popularity in Kazakhstan. Carbon fiber external reinforcement systems are designed to repair and strengthen the load-bearing structures of artificial structures in order to eliminate the consequences of concrete destruction and reinforcement corrosion as a result of prolonged exposure to natural factors and aggressive environments during the operation of structures.

At the stage of construction and operation, the external reinforcement system allows you to solve the following tasks: eliminate design or execution errors, increase the load-bearing capacity of structures with an increase in design loads, as well as eliminate the consequences of damage to load-bearing structures that occurred during operation.

External reinforcement systems are extremely easy to use. The technology involves gluing high-strength materials to the surface of the reinforced structure using epoxy compounds. The advantages of using an External Reinforcement System are obvious. This is primarily a reduction in time and labor costs. When reinforced with an external reinforcement system, no additional bulky equipment is required. Work can be carried out without stopping the operation of artificial structures [1].

**System of external reinforcement of elements of building structures of artificial structures:**

* Installation of elements with high tensile strength on the surface of the stretched zone of the reinforced structure;
* Joint work with the reinforced structure is provided by special compositions;
* The efficiency of including the gain in the work is determined by the distance from the compressed zone of the element, the further away, the more effective.

External reinforcement is used to increase the seismic resistance, strength and reliability of the structures being built with an increase in the time between repairs while maintaining the material consumption (Fig. 1). If we talk about the reconstruction of artificial structures, it is assigned when strengthening load-bearing structures to perceive increased loads or ensure performance according to a modified design scheme. And for reinforcement, it is used to eliminate the consequences of concrete destruction and reinforcement corrosion as a result of prolonged exposure to natural factors and aggressive media or mechanical impact.
The use of this type of reinforcement has a number of advantages over traditional methods. This is a high tensile strength, corrosion resistance, ease of use, no dimensional restrictions. The success of using composite materials to strengthen building structures depends not only on the choice of effective composites, but to a large extent on solving the problems of compatibility of their work with the restored or reinforced structure. For this purpose, it is important to choose materials and technologies for repairing the destructive surface of reinforced concrete, ensuring their high adhesion in the substrate. This repair layer should be a reliable base for gluing reinforcing composite materials and working with them together. Preparation of the reinforced concrete structure for repair and subsequent strengthening should include measures to protect against corrosion of the reinforcement, which develops at the first signs of destruction. Without special measures, the resulting corrosion products will tear off the protective layer from the repair materials, which will negate the work on the sticker of composites [2-3].

The repair system provides for the use of materials and technologies that ensure stopping and preventing further corrosion of reinforcement and concrete, reliable adhesion of repair compounds with old concrete, increased water resistance, frost resistance and chemical resistance. These materials include: penetrative corrosion inhibitors of rebar, polymer-cement dry mixes with a fast set of strength, special latex emulsions that increase adhesion to old concrete, protective coatings to prevent the penetration of chlorine ions, low-viscosity epoxy compounds for repairing cracks and special epoxy compounds for repairing structures in conditions of high humidity and under water [4].

The repair system also includes reinforcement of structures, which is carried out by external reinforcement with particularly high-strength fabrics made of carbon and special glass fibers on an epoxy binder (Figure 2). Reinforcing elements are created by applying appropriate fabrics to the repaired surface with special epoxy compounds that provide reliable adhesion to concrete and repair materials [5].
Application of composite materials for seismic reinforcement

Seismic reinforcement of building structures using carbon fiber-based external reinforcement systems in earthquake-prone areas with a seismicity of 7, 8 and 9 points can reduce seismic loads by 1.5-4 times, depending on the specific conditions of artificial structures.

The principle of seismic reinforcement of structures with carbon fiber is to stick with a special epoxy adhesive on the surface of structures of high-strength canvases or laminates, as well as mesh. It is possible to strengthen both bent structures in stretched zones and on supporting areas in the zone of action of transverse forces, and compressed and off-center compressed elements (Fig. 3).

Traditional methods of seismic reinforcement of artificial structures include the creation of reinforced concrete jackets, reinforcement of shotcrete with concrete, the introduction of additional reinforced concrete and metal frames, clips, etc.

The external reinforcement system increases the ability of buildings and structures to withstand earthquakes with minimal damage due to: strengthening of columns, strengthening of load-bearing walls, strengthening of inter-floor floors and coatings that work as stiffening diaphragms that ensure the distribution of seismic load between vertical load-bearing elements.
Advantages of external reinforcement over traditional methods of strengthening structures

There are several advantages of using external reinforcement in comparison with traditional methods gain: cost savings; reduced labor costs (no need to involve heavy equipment); the ability to perform work without interruption of production or traffic reduction the repair costs (increase of overhaul period); the possibility of correcting errors in the design and construction; low weight gain (not weight original design); the minimum space requirements for the execution of the works; resistance to all aggressive media; high adhesion to the reinforced structure; no welding operations; minimum thickness of reinforcement.

As an example, we can give two types of materials for external reinforcement, presented below. FibARM Tape 530/600 carbon tapes are used for covering reinforcement of columns and pylons, broadband reinforcement of slabs, structures with increased requirements for suture reinforcement, covering reinforcement of concretes with large-scale grid cracking. Carbon nonwoven fabric FibARM Spread Tape is used to increase the contact area of bundles, increase adhesion to the substrate, improve the quality of impregnation, uniform distribution of carbon fibers in the cross section, reduce the consumption of binder, reduce the total thickness of the reinforced structure. Especially for external reinforcement of FibARM, the epoxy adhesive FibARM Resin has been developed, which, in turn, has high physical and mechanical characteristics, high adhesion to surfaces, is convenient for impregnating fabrics by hand, is suitable for fabrics of any density, and does not require separate primer compositions [6-10].

Calculations for strengthening elements of building structures of artificial structures

The tensile stresses perceived by the IAS are determined from condition (1):

\[ \sigma_{fu} = \varepsilon_{fu} E_f \leq R_{fu} \]  

The calculated strain is limited by the ability to transfer stress to the substrate through the adhesive. The effective anchorage length is determined by the formula (2), but not less than 100 mm:

\[ L_f = \frac{23300}{(nt_f E_f)^{0.58}} \]  

The total load-bearing capacity of a reinforced stretched element is determined from the following condition (3):

\[ N_{\text{max}} = R_s A_s + R_{fu} A_f \]  

For off-center compressed elements (columns of rectangular cross-section), it is determined by the formula (4):

\[ K_a = 1 - \frac{(b - 2r)^2 + (h - 2r)^2}{3bh(1 - \mu)} \]  

\( K_a \) – efficiency coefficient of the cage, for round-section columns accepted \( K_a = 1.0 \).

The permissible limit stresses in the cage are determined by the formula (5):

\[ \sigma_R = \frac{k_d \rho_s E_f}{2} = \frac{k_d \rho_f 0.75 R_f}{2} \]  

The calculated resistance of concrete of a column reinforced with a solid cage in height is determined by the following formula (6):

\[ R_{bc} = R_b (2.254) \sqrt{1 + \frac{7.94 \sigma_s}{R_b} - \frac{2 \sigma_s}{R_b} - 1.254} \]  

In the case of using separate clips, the calculated resistance of concrete is determined by multiplying the value by the coefficient \( K_e \), calculated graphically, as shown in Figure 4:
The maximum concrete force of the compressed zone is determined by the formula (7):

\[ N_b - R_f A_f - R_{fu} A_f = 0 \quad (7) \]

The height of the compressed concrete zone of the reinforced element is determined from the condition (8):

\[ x = \frac{N_b}{R_f b} \quad (8) \]

The distance between the ultimate force of the concrete of the compressed zone and the resultant force in the stretched reinforcement and external reinforcement is determined from the formula (9):

\[ z_b = \left( h - a_p - 0.5x \right) \quad (9) \]

The maximum bending moment that can be perceived by the cross-section of the reinforced element is determined by the formula (10):

\[ M_{wi} = N_b z_b \quad (10) \]

**Conclusions:** The need to monitor the stress-strain state of structural elements of artificial structures reinforced with a carbon fiber seismic reinforcement system is caused by the inevitable aging of the material from which they are made, the constant change (increase) in operational loads and the influence of natural and climatic factors.

Structures with a carbon fiber seismic reinforcement system have the following advantages over structures with conventional anti-seismic measures:

- Installation increased reliability and safety-reduced seismic response during an earthquake prevents damage and collapse of artificial structures, protecting people, their property and transport;
- Ensuring uninterrupted operation of vital production systems - electricity supply, operation of the water supply network, fire extinguishing systems and other engineering communications and structures;
- Reducing the cost of artificial structures - in comparison with traditional antiseismic measures carried out with structural elements, the cost is reduced by 5-20%;
- Reducing the cost of operating an artificial structure - the service life of at least 50 years, these are the only elements of seismic protection that are responsible for the seismic resistance of the structure as a whole.

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ЛИТЕРАТУРА

АРМИРОВАНИЕ ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ КОМПОЗИТНЫМИ МАТЕРИАЛАМИ

Бондарь Иван Сергеевич, к. т. н., сениор-лектор Казахская академия транспорта и коммуникаций им. М. Тынышпаева, г.Алматы, Казахстан, ivan_sergeevich_08@mail.ru.

Салман Аль Дулайми Салман Дауд, к. т. н., доцент, Национальный исследовательский Мордовский государственный университет им. Н. П. Огарев, г.Саранск, ул. Большевистская, 68, Российская Федерация, Республика Мордовия, E-mail: salmoon-1985@mail.ru.

Алдекеева Динара Танашбековна, к. т. н., доцент, Казахская академия транспорта и коммуникаций им. М. Тынышбаева, г. Алматы, Казахстан, aldekeeva69@mail.ru.

Куатбаева Токжан Куангалиевна, д. т. н., профессор кафедры "Строительство и строительные материалы", Университет имени К.И.Сатпаяева, г.Алматы, Казахстан, E-mail: tk-kuatbaeva1@mail.ru.

ТЕМПЕРАТУРНОЕ КОМПОЗИЦИОННОЕ УПЛОЩЕНИЕ ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ КОМПОЗИТНЫМИ МАТЕРИАЛАМИ

Бондарь Иван Сергеевич, т. ф. к., сениор-лектор, М. Тынышбаев атындағы Қазақ көлік және коммуникация академиясы, Алматы, Қазақстан, ivan_sergeevich_08@mail.ru.

Салман Аль Дулайми Салман Дауд, т. ф. к., доцент, Н. П. Огарев атындағы Мордва ұлттық зерттеу мемлекеттік университеті, Саранск, Большевистская көшесі, 68, Ресей Федерациясы, Мордовия Республикасы, E-mail: salmoon-1985@mail.ru.

Алдекеева Динара Танашбековна, т. ф. к., доцент, М. Тынышбаев атындағы Қазақ көлік және коммуникация академиясы, Алматы, Қазақстан, aldekeeva69@mail.ru.

Куатбаева Токжан Куангалиевна, т. ф. д., “Құрылыс және құрылыс материалы” кафедрасының профессоры, Сәтбаев атындағы Университет, Алматы, Қазақстан, E-mail: tk-kuatbaeva1@mail.ru.

Аңдатпа. Жөндөу жүйесі арматура мен бетонның коррозиясын төкетудө және ордан әрі дамытуы болдырмайды, жөндөу құрамдарының ескі бетонмен сенімді ұсталуын, су өткізу құралындық, эркін тәуелділікті және химиялық тәуелділікті арттыруды қамтамасыз етеді. Бұл мақалада FibARM құрамдары туралы айтылады, олар қорылысқа және ортамға қолданылады, олар құрылысқа және ортамға қолданылады. Бұл мақалада жөндөу жүйесінің құрылысқа және ортамға қолданылады.

Түйінді сөздер: жасанды құрылымдардың конструкцияларын күшейту, сыртқы арматура мен бетонның коррозиясын төкетудө және ордан әрі дамытуы.