

Destruction of reinforced concrete structures of sewage systems

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Abstract. Composites materials are artificially created materials that consist of two or more components that differ in composition and are separated by a pronounced boundary. The development of modern composite materials is associated with the discovery of high-strength whiskers, with the study and use of aluminides and high-strength alloys. At present, various composite materials have been developed and used: fibrous; reinforced with whiskers and continuous crystals and fibres of refractory compounds and elements; dispersion-hardened materials; layered materials; alloys with directional crystallization of eutectic structures; alloys with intermetallic hardening. There are many technologies for producing composites: imbibition of reinforcing fibres with matrix (base) material; cold pressing of components followed by sintering; sediment of the matrix by plasma spraying on the hardener, followed by compression; batch diffusion welding of multilayer tapes of components; joint rolling of reinforcing elements with a matrix, and etc. The use of composites makes it possible to reduce the weight of aircraft, cars, ships, increase the efficiency of engines, and create new constructions with high performance and reliability. The development of composites with high impact resistance is an important direction in the industry. The strength characteristics of a layered composite material are decisive ³under shear loads, loading of the composite in directions other than the orientation of the layers, and cyclic loading. In this paper, we study the non-stationary interaction of an absolutely rigid body on a two-layer reinforced composite material. The action of the striker is replaced by a non-stationary vertical even distributed load, which changes according to a linear function, in the area of initial contact, which is assumed to be unchanged over time.



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In contrast to the previous articles (Parts I and II), in this papers there is an investigation of the strain-stress state, the fields of the Odquist parameter and normal stresses depending on the material of the first (upper) layer.

Keywords: plane, strain, impact, composite material, armed material, reinforced material, elastic-plastic, deformation.

INTRODUCTION

Since the main share of elements and constructions of sewage underground structures are composed reinforced concrete elements (ZBE) and structures (ZBK) of different types and purposes, and the main type of concrete corrosion,

determining, mainly, the corrosion state of steel reinforcement and engineering reinforced concrete structures in general, and, as a result, the technical quality of construction structures that are operated in various chemically aggressive environments, is the carbonization of concrete (Fig. 1, 2), then the study of its features under the influence of many factors, a lot of attention is paid in domestic and foreign source. However, despite many years of research, many authors do not have a single opinion either on the influence of carbonation on the physical and mechanical characteristics of concrete, or on the influence of technological and climatic factors on the development of carbonation. Since the results of research by scientists and practitioners not only differ significantly, but also often are contradictory in nature, which does not allow acceptance you to a unified opinion about the mechanism of carbonization, and the features of this process, in connection with which we conducted additional studies.



Fig. 1. Photograph of a section of a reinforced concrete sample with traces of carbonation of the protective layer of concrete near the reinforcement. x10. (Photo by the authors).

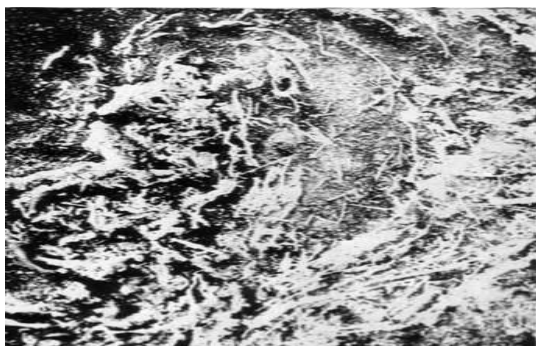


Fig. 2. Traces of carbonization of the protective layer of reinforcement of reinforced concrete structures. x10. (Photo by the authors).

METHODS AND MATERIALS OF EXPERIMENTAL RESEARCH

The methodology for research was chosen according to the European standard ENV206, the Italian UNI9858 and the British 8110BS, which also recommend methods for ensuring the durability of concrete structures reinforced with steel rods. First of all, the depth of carbonization of concrete was determined by applying an indicator solution of phenolphthalein. In addition, a method was used, according to which the depth of carbonization was estimated by the change in the value of the hydrogen pH indicator. The thickness of corrosion products on reinforcing rods was determined with a micrometer, as well as with a device that measures the thickness of non-magnetic coatings on steel.

Production of concrete samples in the size of 800x80x100mm with reinforcement with a diameter of 10mm (A240) with a protective layer of thickness 10; 15 and 20 mm were performed according to the requirements of BNiP of Ukraine 2.03.01.-84 "Concrete and reinforced concrete structures". The composition of the concrete mixture: granite crushed stone with the size of fractions 5-11 mm with the grade of granularity M1000. Micro sand = 22-3 mm. Cement-class 42.5 brand 500 in the amount of 520 kg/m³; sand -700 kg/m³; crushed stone - 1038 kg/m³; the water-cement ratio was equal to V/C=0.4; V/C=0.45; V/C=0.6; V/C=0.7. Cement grade 500. Concrete class B40. Reinforced concrete samples were placed on a special stand in a model solution of salt water (1%NaCl), where carbonic acid anions HCO₃⁻=360-600mg/l were added; sulfuric acid anions SO₄²⁻= 14-25 mg/l; carbon dioxide CO₂ = 5.5-11 mg/l. Hydrogen sulfide was passed through the model solution, which was H₂S = 11-14 mg/l. The duration of exposure of concrete samples in the solution was from 800 hours. up to 3 months. In addition, concrete samples with a cross-sectional size of 30x30 were made; 40x40 and 50x50 mm. The length of all samples was equal to 500 mm. Experimental studies of the bond strength of concrete mortar with reinforcing bars were carried out at the installation according to the methodology of the company "Sif-Isopipe" (France) - Fig. 3.

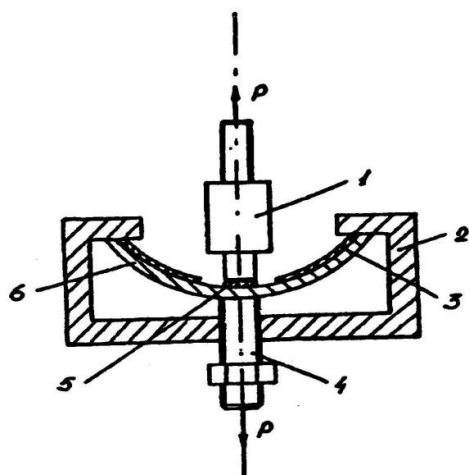


Fig. 3. Scheme of the device for determining the strength of adhesion (adhesion) of the concrete solution to the reinforcement by the pull-off method. Designation: 1 – fungus; 2 – bracket; 3 – concrete coating; 4 – emphasis; 5 – transitional layer between reinforcement and concrete solution; 6 – reinforcing rod

It should be noted that the concrete solution was prepared in a concrete mixer with a capacity of $V=50$ l. The samples were kept at a temperature of 20°C in a room with a humidity of 60% until the formwork strength was reached for 14 hours. Then the samples were placed in a steam chamber with a heat treatment mode - heating from 20°C to 60°C . The term of isothermal heating - 6 hours, then cooling from 60°C to 25°C - 16 hours.

After the end of the corrosion process of the armature (the appearance of a longitudinal cracking crack with a width of 0.2-1.0 mm on the samples, the samples were taken out of the solution after 3 hours and subjected to tests on the installation (Fig.5). Corrosion products from the armature were removed mechanically and with a 10% HCl solution.

Sampling (core) was carried out regularly, every 100 hours. (when determining the penetration of chloride, sulfuric and carbonic acid ions). To obtain the core, holes with a diameter of 10 mm were drilled in different places of the slabs. The carbonation process was studied every 10 days. Also, similar experiments on the study of carbonization were conducted for concrete of different strength classes. The results of the experiments are shown in Fig. 3-5.

NUMERICAL SOLUTION

The data in Fig. 4 show that with an increase in the exposure time of reinforced concrete samples in model solutions, the depth of carbonation along the reinforcing rods increases. Moreover, it should be noted that the experimental data correlate well with the calculations made according to the models presented in the works [1]. Moreover, the greatest similarity was obtained when using models for calculating the depth of carbonization, which were proposed by specialists of the Lviv Polytechnic [2]. It should be noted that a small difference in the experimental and calculated data is inherent in approximately the period of exposure of the samples, which is on average 300-400 hours. Such an exposure term can be explained by observing the diffusion mechanism of carbon dioxide (CO_2) transport through the capillaries of concrete, and when the penetration depth in concrete is 20 mm or more, it is likely that CO_2 gas spreads into the depth of the concrete by other mechanisms, for example, it is carried by liquid or convection.

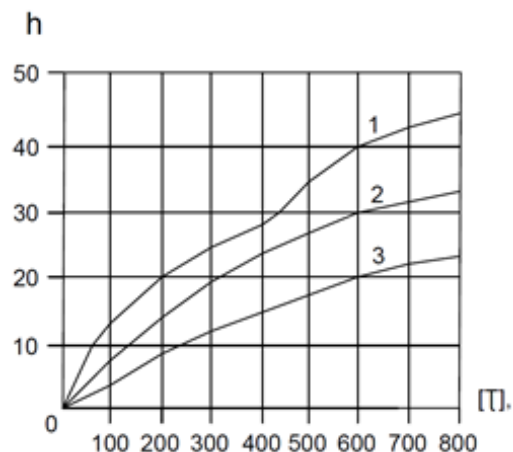


Fig. 4. Carbonation depth of concrete (h) with a W/C ratio of 0.4 and $Q=400$ kg/kg of cement depending on the exposure period. Notation: 1 – experimental data; 2 – calculation curve according to Professor Leonovych's model; 3 – calculation curve according to the Lviv Polytechnic model

The data in Fig. 5 confirm what is known in the literature, in particular, an increase in the strength of concrete (from 10 to 70 MPa) leads to a decrease in the depth of carbonization by approximately 5-6 times. Moreover, concrete

with a strength of 45-70 MPa has low carbonation. It should be noted that for concrete with a strength of 30-70 MPa, the similarity of experimental and calculated results is inherent.

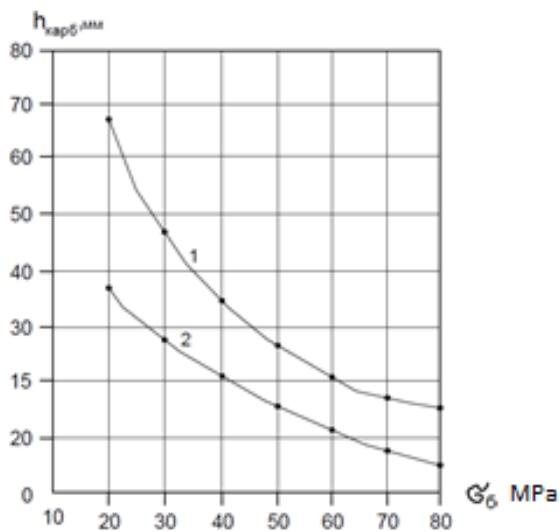


Fig. 5. Dependence of the actual carbonation depth of concrete on its strength (class)

To the above are added questions regarding the assessment of carbonation parameters: First of all, the carbonation reaction is based on the theoretical calculation of the movement of CO_2 molecules into the depth of the concrete beyond the neutralized layer until the moment they complete absorption, and when the depth of the reaction zone does not exceed exceeds 1 mm. This, unfortunately, is not confirmed experimentally them by the results of the study of the interaction of carbon air gas with calcium hydroxide, which forms the basis of the pore liquid of concrete, according to which the reaction takes place in a thin surface layer of the solution with the appearance and growth of crystals left carbonate without removal of reaction products [2].

As is known, the generally accepted mechanism determines the movement of carbonification linearly into the depth of concrete, which fully corresponds to the passage of carbonization in the real process of operation of a reinforced concrete structure.

The process of carbonization consists in the interaction of carbon dioxide from the air with the cement stone of concrete, as a result of which the alkalinity decreases concrete and the

passivating effect on the steel reinforcement is lost. To a large extent, the rate of carbonization depends on the prothickness and thickness of the protective layer of concrete. Mass damage to structures for the specified reason is observed during the mixing of low-quality concrete with increased water-cement relation and as a result with increased permeability for carbon dioxide. Very common cases of corrosion due to reduced thickness of the protective layer (hidden defect).

To prevent this type of damage to reinforced concrete structures this is easy enough. It is necessary to appoint and realistically ensure the thickness of the protective layer and the grade of concrete for waterproofing, recemented BNiP 2.03.11-85. Concrete grades for waterproofing ticks W6—W8 are practically not carbonized.

In recent years, industrial data indicate a significant contribution of biodegradation to processes of destruction of building materials, including concrete. In connection with this, the task of impact assessment arose biofactor on the processes of destruction of concrete of hydro-technical structures, including underground sewage systems [2, 8].

Biological corrosion of concrete is a process of damage to concrete that occurs as a result of the vital activity of living organisms organisms such as bacteria, fungi, etc., which are inhabited on the surface of building structures. Biodegradable microorganisms.

Tors can cause the destruction of almost any building materials and structures, including concrete. Biodamage of mineral building materials is reduced to a violation of the adhesion of the constituent components of these materials [2, 3]. The most active in corrosion are lithotrophic bacteria that oxidize inorganic compounds. For example, nitrifying bacteria that obtain energy by oxidizing reduced inorganic nitrogen compounds, including ammonia that is constantly present in the sewage environment, the process leads to the formation of nitric acid. So nitric acid is the cause destruction of building materials. No less destructive role the second group of bacteria - oxidizing sulfur compounds - wins.

Bacteria, in particular, can destroy not only

concrete, but also steel reinforcement. In this case, the action of microorganisms is of a bioelectrochemical nature. Many authors note the effect on metal of acid-forming bacteria, such as sulfate-reducing, nitrifying, and thionic bacteria [3,4].

The effect of chloride solutions on steel reinforcement in concrete. When penetrating or entering concrete of chloride salts, it loses its passivating effect on steel fittings (Fig. 5). On the surface of the steel develops electrical chemical corrosion resulting in dissolution steel with the formation of a layer of corrosion products (rust). The formed corrosion products exert pressure on the protective a layer of concrete, which, not having high strength, especially under tensile stresses, collapses.

Chlorides are dangerous due to their aggressive effect on steel fittings. Getting into concrete with initial materials from the environment: they cause depassivation and corrosion of steel reinforcement. As the humidity and temperature of the environment increases, the diffusion rate of chlorides in concrete increases, which is typical for regions with a warm, humid climate. In work [5] it is reported that with the change in temperature and humidity of the climate in the last 100 years, the service life of reinforced concrete structures of hydraulic structures of Ukraine has decreased by 10-12 years.

It should be noted that a certain amount of chlorides can get into concrete with starting materials: cement, aggregates, mixing water, additives.

The actual amount of chlorides that can cause steel rebar corrosion depends on many factors, the main one being the composition of the cement.

Table. 1. The rate of corrosion of concrete in chlorine solutions

Вміст хлор-іонів в розчині, мг/л	Швидкість корозії бетону, мм/рік
5	3
50	10
100	20

Corrosion begins when the amount of chlorides in each of the listed materials reaches the

maximum allowable for each material and exceeds 0.4% of the mass of cement, i.e. The amount permitted by the norms of BP 28.13330 "Protection of building structures against corrosion". However, when using high-aluminate portland cement, corrosion of steel reinforcement begins at a higher chloride content than specified in BP 28.13330 [6].

During carbonization of concrete, the amount of bound chlorides decreases; at the same time, the pH of concrete decreases, which increases the aggressive effect of chlorides. It follows that carbonation of the protective layer of concrete must be eliminated in chloride environments.

The main means of primary protection of steel reinforcement against chloride corrosion in concrete is the assignment of standardized permeability values and the thickness of the protective layer (tablet). The experimental results of determining the depth of carbonization depending on the content of chlorine ions in concrete are shown in Fig. 6.

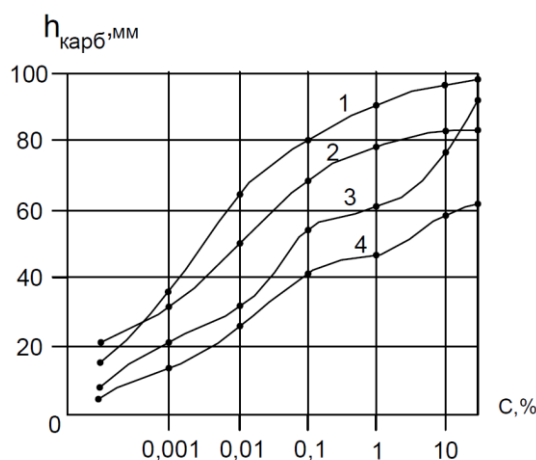


Fig. 6. Dependence of the depth of penetration of chlorine ions into the depth of concrete on the concentration of salt in the aqueous solution. Designation: 1 – concrete class B40 (50 years of operation); 2 – concrete class B40 (30 years of operation); 3 – unused concrete of class B40; 4 – unexploited concrete of class B60. The exposure period of the samples in the solution is 820 hours.

The analysis of the data presented in Fig. 5 shows that the increase in the concentration of chlorine ions in the concrete solution leads to an

increase in the depth of carbonization, regardless of the class of concrete (B40 and B60) and the service life. But at the same time, there is also a peculiarity - a sharper increase in the depth of carbonization with an increase in the service life of reinforced concrete, in particular, the depth of carbonization of concrete with a service life of 50 years is 10-20% greater than that of concrete with a service life of 30 years.

The analysis of the data shown in Fig. 6 shows that shotcrete and concrete with a water-cement ratio equal to 0.4-0.45 have the highest bond strength of reinforcement with concrete and, as a result, high crack resistance. That is, an increase in the V/C ratio causes a decrease in its adhesion to the reinforcing bars. Attention is also drawn to the fact that the crack resistance is sharply manifested when the deflection of the beam is up to 5-10 mm, and then the crack formation subsides, that is, it slows down, which can be explained by the effect of the initial destruction of weak connections with the reinforcement due to, apparently, the imperfect technology of curing reinforced concrete. installation and natural defects, features of corrosion product placement on the surface of the armature, etc.

Numerous domestic and foreign studies have established critical concentrations of chlorides in concrete, above which there is a danger of corrosion of reinforcement (on average, they are 0.1-0.5%). For structures with conventional reinforcement, the critical amount of chlorides depends on the type of cement and the density of the concrete. In international practice (European standards), 0.5% of chloride ions by weight of cement and 0.1% for prestressed structures are accepted as the maximum permissible values for structures with non-stressed reinforcement.

In the practice of operation of reinforced concrete structures in sewage underground structures, it was established that a very large number of destructions of reinforced concrete structures were subjected to chloride corrosion. As it was established as a result of additional surveys, household and industrial effluents (waste) often contain chlorine-containing reagents and also contain household chlorides.

With the development of concrete manufacturing technology in recent decades, and with the development and mass use of effective chemical additives, it became possible to reduce the permeability of concrete to a level that postpones the moment of accumulation of a critical amount of chlorine.

Streaks on the surface of the armature for a long time. Applying superplasticizers, it is possible to reduce the water-cement ratio to the level of the water-cement ratio of the cement dough is normal density This makes it possible to reduce the permeability of concrete, which can be estimated by the value of the diffusion coefficient, which can reach values of the order of 10^{-9} cm²/s. The data of experimental studies, shown in Fig. 5, show how the concentration of chlorine ions affects the depth of penetration of chlorine through the thickness of concrete. It can be seen that with the increase in the concentration of chlorine (in terms of the salt content in the aqueous solution in percent), the penetration of chlorine ions into the depth increases sharply. of concrete at a distance exceeding the thickness of the protective layer of reinforcing rods. Moreover, stronger concrete has lower permeability, as well as concrete with a shorter service life.

The samples of the presented series are characterized by an increase in the deformation of reinforced concrete only as the corrosion damage of the reinforcement increases. At an insignificant level of damage to the reinforcement, there is a decrease in the forces of adhesion of the reinforcement to the concrete, which is caused by additional compressive stresses at the border of the contact of the reinforcement with the concrete from corrosion products. It should be noted that the "Methodology for calculating deflections according to BNiP52-101-2000" too accurately describes the behavior of reinforced concrete structures subjected to bending deformation and corrosion, however, in case of significant corrosion damage, the destruction of reinforced concrete beams occurs at significantly lower loads (on average, by 15-20% relative to samples without traces of corrosion). However, determining the limit value of corrosion of the reinforcement, up to which the im-

provement of the adhesion properties of the reinforcement with concrete occurs, is a separate task that needs to be paid attention to in future studies

CONCLUSIONS

Thus, there is a dependence between the level of corrosion of reinforcement and indicators of adhesion of reinforcement with concrete, strength and deformation properties of reinforced concrete beams, and therefore the following factors that determine the degree and nature of corrosion damage to reinforced concrete structures must be taken into account. The most important characteristics include:

1. Characteristics of concrete: initial value of modulus of elasticity for compression, tension; porosity;
2. Physical and mechanical characteristics of reinforcement: strength, deformations, steel grade, and type of variable section;
3. Protective layer of concrete and its form;
4. The ratio of the bending moment, which creates compressive or tensile stresses in the concrete near the reinforcing zone, to the moment of crack resistance of the reinforced concrete element;
5. The aggressive nature of the environment should be taken into account.

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Руйнування залізобетонних конструкцій каналізаційних систем

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Анотація. Композиційні матеріали це штучно створені матеріали, які складаються з двох або більше компонентів, що відрізняються за складом і розділених вираженою межею. Розвиток сучасних композиційних матеріалів безпосередньо пов'язане з відкриттям високоміцних ниткоподібних кристалів, розробкою нових армуючих матеріалів, з дослідженнями та застосуванням алюмінідів і високоміцних сплавів. В даний час розроблені і застосовуються різні композиційні матеріали: волокнисті, армовані ниткоподібними кристалами і безперервними кристалами і безперервними волокнами тугоплавких з'єднань і елементів, дисперсно-зміцнені матеріали, шаруваті матеріали, сплави з спрямованою кристалізацією евтектичних структур, сплави з інтерметалідним зміцненням. Існує безліч технологій отримання композитів: просочення армуючих волокон матричним (основним) матеріалом; холодне пресування компонентів із наступним спіканням; осадження матриці

плазмовим напиленням на зміцнювач з наступним обтисканням; пакетне дифузійне зварювання багатошарових стрічок компонентів; спільна прокатка армуючих елементів з матрицею та ін. Застосування композитів дозволяє знизити масу літальних апаратів, автомобілів, судів, збі-

льшити Коефіцієнт корисної дії двигунів, створити нові конструкції, що володіють високою працездатністю і надійністю. Розробка композитів з високою опірністю ударним навантаженням є важливим напрямом у промисловості. Міцні характеристики шаруватого композиційного матеріалу є визначальними при зсувних навантаженнях, навантаженні композиту в напрямках, відмінних від орієнтації шарів, і циклічних навантаженнях. У цій роботі досліджується нестационарна взаємодія абсолютно твердого тіла на двошаровий зміцнений композитний матеріал. Дія ударника замінюється нестационарною вертикальною рівномірно розподіленою навантаженням, що змінюється по лінійному закону, в області початкового контакту, який передбачається незмінним з плином часу. Передбачається жорстке зчеплення шарів між собою. Процес удару моделювався як нестационарне завдання з рівномірно розподіленим навантаженням в області контакту, що змінюється за лінійним законом. На відміну від попередніх статей (частина I і II) у цій статті досліджується напружено-деформований стан, поля параметра Одквіста і нормальних напруг в залежності від товщини першого (верхнього) шару.

Ключові слова: плоска деформація, удар, композитні матеріали, армовані матеріали, броньовані матеріали, пружнопластична, деформація.