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Resistance of cement stone in sanitation solutions

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Abstract. Biological corrosion is a type of effect that influences almost all possible construction projects. The primary measures for its prevention include sanitary and preventive work carried out using various chemicals. The shortcoming of buildings chemical treatment is the degradation effect on building composites with a significant reduction in the life of structures. The subject of the study was presented by the aggressive effect degree of sanitation treatment on various compositions of cement stone assessment. During the research Portland cement and aluminous cement, samples were exposed in two mediums – reagent solution (experimental medium) and tap water (control medium). The degree of medium influence on the cement stone samples was estimated according to the data on the main physic and chemical parameters of the process and phase-structural transformations of the stone after aging in an aggressive environment. There was an increase in the strength of samples after 6 months of exposure both for Portland cement stone and aluminous cement stone compared to the samples aged in pure water and original samples without exposure that showed the absence of the degradation effect of decontamination solution on the cement stone. The increase in the strength of materials occurred due to the intensification of carbonization processes in the sanitation agent medium resulting in the mud injection of pores and voids due to the crystallization of insoluble calcium carbonates. It was confirmed by the compaction of the micro-structure of cement stone expressed by the increase in the mass of samples and the total concentration of carbonate compounds in the volume of the material after 6 months of exposure.

1. Introduction

A significant increase of industrial impact on ecosystem associated with urbanization makes it necessary to monitor and control the process in terms of the harmful effects of production on the environment, as well as the degradation of buildings and structures as a result of the influence of various factors [1–6].

The corrosion of building materials, in the surroundings of which a person spends up to 80 % of his life, is one of the main problems in the context of the globalization of technological development. This is primarily due to the increase in the number of industrial enterprises; frequent disregard of building regulations in the process of waterproofing of certain parts of buildings and structures; the lack of proper ventilation. Biological corrosion is a type of effect that influences almost all possible construction objects [7–15]. At the same time it is obvious that in the case of agricultural enterprises, the problem of structural degradation as a result of the life of living organisms is especially acute, since it is aggravated by the annual increase in the number of farms and production facilities, as well as the number of various livestock farms.

Nowadays, the problem of biological deterioration of buildings and structures of the enterprises of agro-industrial complex is being solved using sanitary and preventive measures. This process covers a whole range of measures for the rehabilitation of buildings, in particular, disinfection, desinsection and disacification, cleaning the area around an enterprise, as well as preventive treatment of equipment. The measures for the disinfection of buildings are planned in advance by zoo engineers in accordance with the technological map of livestock movement.

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Despite the existing variety of methods for the control of pathogenic micro-flora (physical, mechanical, chemical, biological, as well as mixed), chemical methods are the most widely used. They include the use of substances of various compositions that provide a detrimental effect on pathogenic microorganisms [16–20]. It is necessary to note that the use of chemical control methods, despite obvious advantages (almost complete destruction of pathogenic micro-flora), is associated with significant disadvantages, since frequent surface treatment of structural elements of buildings and structures with caustic substances leads to their degradation due to the destruction under the influence of aggressive acids, leaching of soluble substances. As a result it leads to the formation of additional porosity of materials, micro-cracks and the development of various microorganisms on a surface.

The compliance with high-quality sanitary and prophylactic measures is an important part of technological process for the effective functioning of livestock, poultry, animal husbandry and crop production enterprises. The experience of the operation of enterprises of this type, characterized by a variety of technological features of production, showed that the existing set of measures to maintain the cleanliness of buildings does not provide the necessary degree of sterility, which allows reliable (in an adequate measure) prevention of «biological fatigue» of materials and structures.

It is necessary to note that in the development of building composites of increased durability, the tests in most cases are limited to studying the effects of biological corrosion on the properties of a composite [21–25], however, according experimental data on the influence of natural conditions on the properties and structural characteristics of cement stone, the authors revealed that microorganisms do not have time to fully form in bulk structures and on the surface of a material during the inter-recovery period, characterized by short periods of time [26, 27]. This approach shows that building composites of agricultural objects are more affected by the means used for processing of buildings than by the effects of bio-corrosion agents (bacteria and filamentous fungi, algae in some cases). In this regard, the assessment of the impact and contribution of each type of effect is an important task for the development of methods for prolonging the resistance and stability of materials and building objects as a whole.

According to the above mentioned aspects, the purpose of this study was to assess the impact of sanitation treatment (chemical corrosion) on the change in the physic and mechanical characteristics of cement stone of various compositions and its phase-structural transformations when simulating actual operating conditions.

2. Methods

Portland cement was used as the most spread and studied binder, as well as alumina cement with an initial higher corrosion resistance in relation to certain types of exposure. The researchers used Portland cement CEM I 42.5 N produced by Belgorodsky Cement Enterprise Belgorod, Belgorod Oblast, Russia) and GZ-50 aluminous cement produced by the Pashiiski Metallurgical Cement Plant (Pashiia, Perm Region, Russia). Mineralogical and chemical composition are given in tables 1–4.

Table 1. Chemical composition of Portland cement clinker.

The content of oxides, wt. %								
CaO	SiO_2	Al_2O_3	Fe_2O_4	$CaO_{св}$	SO_3	MgO	R_2O	loss on ignition
65.22	21.48	4.75	4.35	0.20	1.87	0.43	0.20	1.5

Table 2. Mineralogical composition of Portland cement clinker.

Minerals, %			
C_3S	C_2S	C_3A	C_4AF
65.2	15.1	6.0	13.7

Table 3. Chemical composition of aluminous cement.

The content of oxides, wt. %				
CaO	SiO_2	Al_2O_3	Fe_2O_3	other
40.5	10.4	40.10	2.65	6.35

Table 4. Mineralogical composition of aluminous cement.

Minerals, %			
CA	C_2AS	$C_{12}A_7$	other
40	38	10	12

The compositions based on the investigated binders were prepared using a Matest E095 laboratory mortar mixer. The weigh-in of the components of the binder was carried out on an electronic weighting unit with an accuracy of 0.01 g. All the samples were made in metal forms, pre-lubricated with a thin layer of machine oil. The cube samples were formed with an edge size of 20 mm based on Portland cement and alumina cement at a water-cement ratio of 0.3.

For the research of simulation media for each type of cement, 2 batches of sample cubes were formed with 6 cubes for each series of tests: 5 simulation media and 6 months of sample exposure. The cement stone samples that hardened for 28 days were obtained for control. Thus, 84 samples were molded for each type of cement.

After laying in the molds, the samples based on Portland cement hardened for 1 day in a bath with a hydraulic shutter in the molds, then they were redressed and continued to harden for 27 days under the same conditions.

In the case of aluminous cement, after production the molds with the samples were stored for (6 ± 0.5) hours in air-wet conditions at a relative humidity of 90 %, then they were placed in a bath with water. After (24 ± 2) hours from the time of production, the molds were removed from the water, the samples were formed and placed in a bath with water and stored in it for 90 days before the experiment. The period of 90 days was chosen in order to wait for the completion of the process of recrystallization of metastable phases into stable ones.

At the end of hardening process, the samples in the amount of 6 pieces from each type of binder were tested using a PGM-100 hydraulic press, the remaining samples were exposed in simulation media and tested for strength every month.

The researchers used as simulation media the following:

– Piped water. This series of samples was evaluated as control compositions for Portland cement and aluminous samples, respectively (pH = 6.8);

– An aqueous solution of a disinfectant used for the treatment of buildings during the rehabilitation of facilities of the Aldecol DEZ 25 (Germany) agricultural complex, which included: glutaric dialdehyde 12.5 %, formaldehyde 9.5 %, alkyl-dimethyl-benzyl-ammonium chloride 5 %, methanol up to 2.5 %. This product had the 3rd class of hazard and was water soluble. For research, the authors used a solution with an active substance concentration of 0.5 % (pH = 7.09), which corresponded to the recommendations of a producer.

The samples were placed in glass desiccators with a tight lid. They were arranged in such a way that all the faces of the cube were in contact with the simulation medium (Figure 1). For this purpose, a polyethylene net was placed between the samples. During the experiment, desiccators were kept closed and opened once a month for sampling and updating the simulation medium. At the same time the composition of simulation medium was updated every month, thus the medium had constant aggressive effect on the investigated samples.

Figure 1. System for laboratory exposure of samples in model environments.

The testing in all model media was simultaneous and lasted for 6 months, with sampling in order to control such parameters as: pH of the medium, appearance, mass variation, compressive strength, chemical resistance of samples, micro-structural and phase transformations of cement stone.

The pH of aqueous solutions was determined using an OYSTER-16 pH meter. The determination of the pH of the contents of each desiccator (simulation medium solution) was carried out by measuring the pH of the solution before immersion of the samples and after each month of exposure.

The degree of influence of the medium on cement stone was estimated according to the data on mass variation (defined in percents as the difference between the initial and final mass, referred to the initial mass of the sample), as well as the chemical resistance coefficient (the ratio of the strength of samples exposed in a simulation medium to the strength samples aged in piped water).

The analysis of micro-structural changes was carried out monthly throughout the experiment using a TESCAN MIRA 3 LMU high resolution scanning electronic microscope. The microstructure of all compositions was studied by analyzing a representative sample of images, by scanning the entire surface of the sample at magnifications of 200 to 50000 times, with a direct description during shooting. For the subsequent demonstration of the research results, the authors surveyed the areas typical for morpho-structure at identical magnifications for each sample: 350; 5000; 15000; 36000 times.

The phase composition of the initial and aggressive samples was evaluated using an ARL X'TRA X-ray diffractometer. Shooting conditions were: $Cu_{K\alpha}$ radiation, interval of diffraction angles 2θ = 4–64 º, scan step 0.02º, pulse acquisition time – 1.2 sec.

The method of full-profile quantitative X-ray diffraction analysis was used as the main analytical tool for the diagnosis and quantitative determination of weight concentrations of crystalline mineral formations in binders.

Full-profile quantitative X-ray diffraction analysis was performed using the DDMv.1.95e program in the DDM-algorithm version (Derivative Difference Minimization). The advantages of using this algorithm in the calculated full-profile procedures is that there is no need to clarify the parameters of the background line of the X-ray patterns.

During quantitative full-profile X-ray diffraction analysis of Portland cement stone, the main minerals of Portland cement clinker, as well as uniquely diagnosed minerals that reveals its hydration, were examined. For this, the following structural models were used from the structural data base of inorganic substances ICSD: alite (Ca_3SiO_5 triclinic) – 4331-ICSD, belite (β-Ca_2SiO_4) – 81096-ICSD, brownmillerite (C_4AF) (9197-ICSD), portlandite ($Ca(OH)_2$) – 202233-ICSD, calcite ($CaCO_3$) – 16710-ICSD and ettringite – 90823-ICSD.

For a quantitative calculation of the mineral composition, the phases with known crystal lattice parameters, characterized by a constant composition, were chosen. Therefore, C-S-H phases, which differed in inconsistent composition, did not participate in the calculations, which did not indicate their absence in the hydrated cement stone.

The following structural models from the structural data base of inorganic substances ICSD were used to obtain proved ideas about the mineral composition of samples of aluminous cement stone: CA (260-ICSD), CA_2 grossite (16191-ICSD), $C_{12}A_7$ mayenite (29212-ICSD), CA_6 gibonite 5H (34394-ICSD), $Ca_2MgSi_2O_7$ – $Ca_2Al_2SiO_7$ ackermanite-gelenite (67689-ICSD), $CaMg[CO_3]_2$ dolomite (31334-ICSD), β-C_2S (81096-ICSD), α-C_2S (82997-ICSD), $CaSiO_3$ wollastonite 2M (201538-ICSD), $CaTiO_3$ perovskite (62149-ICSD). As structural models of hydrated phases the authors used: CAH_{10} (407150-ICSD), C_3AH_6 (66274-ICSD) and AH_3 gibbsite (6162-ICSD).

3. Results and Discussion

According to the results of a visual assessment of the appearance of cement stone samples aged in a 0.5 % Aldecol solution, it is possible to conclude that the medium has a slight effect on the change in color, surface and other attributes of both Portland cement (Figure 2, a) and aluminous stone (Figure 2, b). The solution of Aldecol was washed, as a result of which a thin white film was seen on the samples, which was easily erased upon contact with the sample (soapy coat).

a b

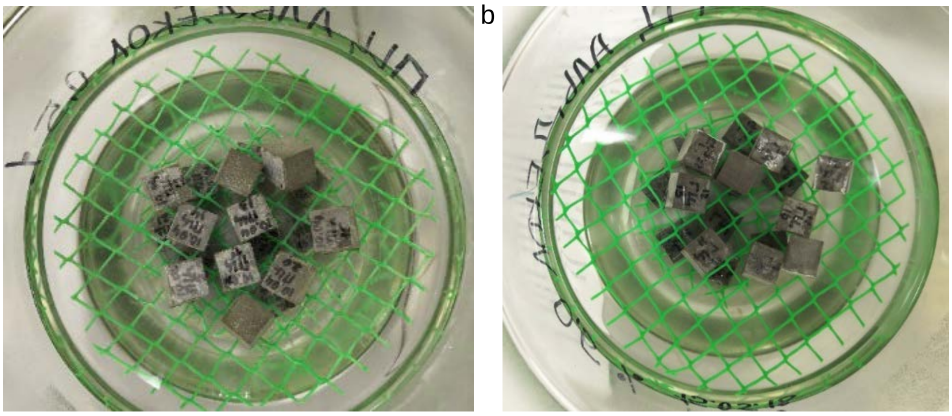

Figure 2. Appearance of cement stone samples, aged in an Aldecol Based Medium: a) Portland cement; b) aluminous cement.

It is necessary to note that the dynamics of changes in the pH-medium with Portland cement stone almost completely coincides with the same indicators for the control (aqueous) medium, not only in character, but also in value (Figure 3, a). A jump was observed in the first month of aging, due to leaching, and then there was a gradual decrease in the value to the initial level when the samples were immersed in medium.

The exposure of samples based on aluminous stone in a control aqueous medium, as in the case of Portland cement, led to a jump in the pH medium in the first month of exposure with further flattening and lowering to the initial value, which was due to the natural processes of dissolution and crystallization in an aqueous medium (Figure 3, b). The change in the pH-medium of the solution of the sanitation agent practically coincided with pure water: at the initial stage, the value increased from 7 to 10, then gradually decreased to the initial value.

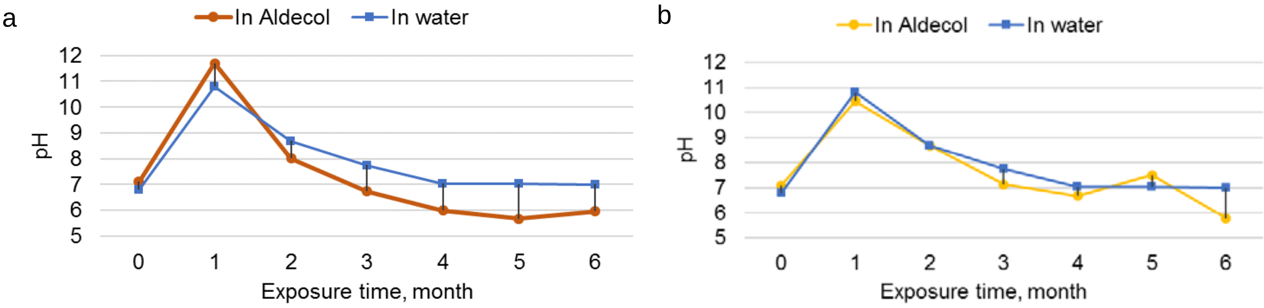

Figure 3. Correlation of changes in the pH-medium of cement stone samples aged in piped water and in Aldecol solution, depending on the exposure time: a) Portland cement stone; b) aluminous cement stone.

The analysis of the dynamics of the mass of cement stone samples depending on the medium and the time period of exposure allowed noting the following. In the case of Portland cement, the nature of the change in the mass of the samples during aging in a sanitation agent and clean water coincided (Figure 3, a): during the first three months there was a uniform increase in weight, the intensity of which further decreased and the mass practically did not change.

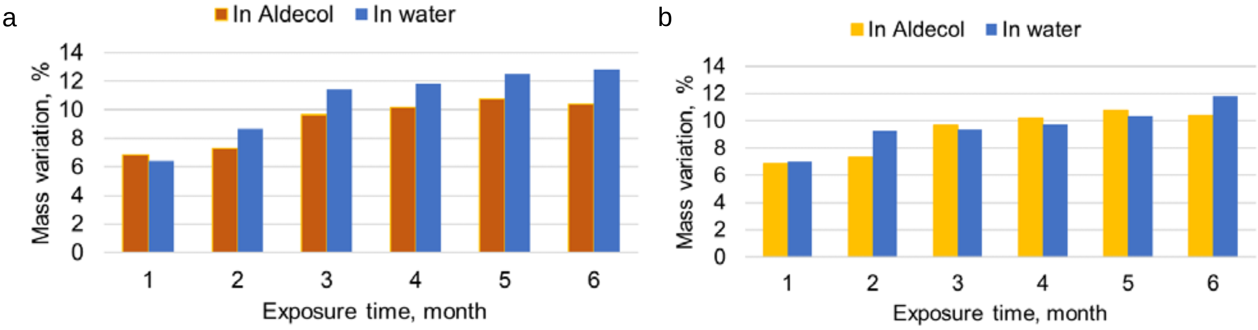

Figure 4. Correlation of changes in mass variation of samples of cement stone aged in piped water and in Aldecol solution, depending on the exposure time: a) Portland cement; b) aluminous cement

From the point of hydration aluminous cement is a more complex system in comparison with classical Portland cement, the kinetics of structure formation of which are significantly influenced by the parameters of the hardening medium. The exposure of samples of aluminous cement stone in water led to the increase in their mass (Figure 4, b). In this case, the mass increase in the second month of exposure compared to the first month was only 2 %. By the end of the experiment (6 months of aging), the total weight increase of the samples was 12 %. A similar character was demonstrated by mass variation of samples in the control medium (Figure 4, b). In addition, the difference in weight increase compared to the control aqueous medium was insignificant regardless of the exposure time of the samples.

Since cement is a binder of hydration hardening, it is obvious that placing samples in an aqueous medium will provide the increase in the final strength of the samples, which is confirmed by the obtained data (Figure 5, a). The increase in exposure time in sanitation agent of Portland cement stone provides the increase in strength compared to the source material by 10 % in the first month and 1.9 times after 6 months of exposure. At the same time, the strength of Portland cement samples is 10 % lower than that for a stone aged in clean water. However, there is the excess of strength after the entire exposure time compared to the control medium. This aspect is determined by a number of factors: for example, the main active ingredient of Aldecol is glutaric aldehyde, which is distinguished by its ability to soften water and also reduce its overall acidity by reducing the amount of carbon dioxide. Probably, in this case, Aldekol acts as an intensifier of carbonization processes in terms of the increase of the amount of crystallized calcium carbonates, in particular, calcite, which acts as an effective colmatant [28]. This is expressed by the increase in the mass of samples noted earlier (Figure 4, a), as well as their strength in comparison with control materials.

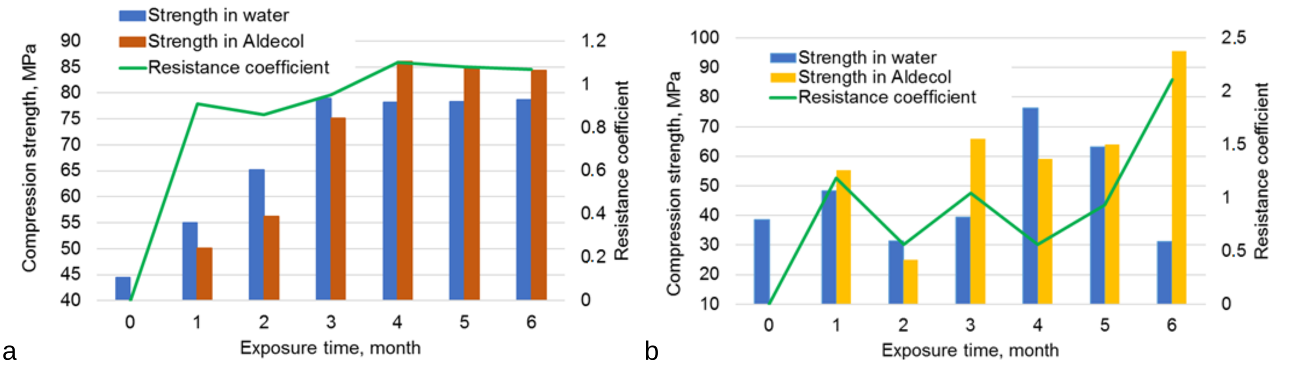

Figure 5. Change in compressive strength and resistance coefficient of cement stone samples aged in piped water and Aldecol solution, depending on the exposure time: a) Portland cement; b) aluminous cement.

The nature of the change in the strength of aluminous stone is distinguished by the absence of a strict dependence on the exposure time (Figure 5, b): after one month of exposure, the increase in strength in water medium (control solution) is 26 %. At the same time, already in the second month, a significant drop in strength is noted: 1.8 times and by 18 % compared to similar indicators after 1 month of exposure and at the age of 28 days, respectively. It can be explained by the hardening of aluminous cement. The initial hardening of the matrix of aluminous stone in the early stages is reasoned by the crystallization of hydro-aluminates of various compositions as a result of hydration processes. A possible explanation for the decrease in the strength of a stone based on aluminous cement after two months of hardening in water is recrystallization of meta-stable highly basic calcium hydro-aluminates into stable forms of hydrated compounds. On the one hand, it is accompanied by the increase in the density of new formations and, on the other hand, by a softening of the system due to the formation of additional voids associated with the decrease in the volume occupied by the crystalline substance.

A further increase in strength can be explained by the hardening of aluminous cement with the excess of water. Under such conditions, at the initial stage, a gel of hydration products is formed in the form of small lamellar X-ray amorphous crystals, which subsequently grow together and form a consolidated framework of the material.

It is necessary to note that the system of hardening aluminous cement is the most unstable due to constantly changing processes of primary crystallization and recrystallization of the formed substance. In this regard, the fluctuations in the strength of aluminous stone, due to the specifics of structure formation in water medium, do not contradict classical ideas about the theory of hydration and hardening of aluminous cement.

The nature of the change in the strength of samples of aluminous cement stone in the medium of the sanitation agent is comparable with the data obtained for a clean control medium (Figure 5, b). Nevertheless, it is possible to note some differences. Thus, as in the case of a clean medium, there is a drop in strength after two months, which, obviously, is associated with the transition of meta-stable compounds into stable and stable hydro-aluminate compounds. Further exposure for 3 months leads to the increase in strength by 1.7 and 2.6 times compared with samples exposed in a control medium of a similar age and two months in a simulation medium, respectively. In the next two months, strength does not change significantly. However, after 6 months, the increase in strength is 3 times in comparison with control materials at the age of 6 months and by 48 % compared to the samples aged 5 months in a simulation medium.

Similar dependences are noted in resistance coefficient, since its value is directly proportional to the strength indices of the samples during aging in simulation media (Figure 5). It is necessary to note that the chemical resistance of aluminous cement in a solution of a sanitation agent is high - the resistance coefficient of all samples, regardless of the exposure time, is more than 1. The following can present a possible explanation for the significant increase in the strength of the matrix of aluminous cement. As it is noted above, Aldecol is characterized by its ability to “accumulate” carbon dioxide in the system. Under such conditions, it is possible to form calcium carboaluminates in aluminous stone, which subsequently decompose into stable insoluble carbonate compounds, in particular, vaterite. This ensures the filling of free space in the stone matrix formed as a result of recrystallization of meta-stable hydroaluminates. As a result, the system is compressed, and the strength of the array increases.

The data on the carbonization of cement stone match the results of quantitative x-ray phase analysis. When analyzing the phases, only the crystalline phase of clearly fixed minerals is taken into account, since the composition of the X-ray amorphous substance, which is mainly represented by calcium hydrosilates of various mineral compositions, can not be identified. The degree of carbonization is estimated by the amount of portlandite as the most soluble phase, actively participating in chemical processes during corrosion, as well as calcium carbonates (calcite, aragonite, vaterite) as an indicator of the degree of carbon dioxide exposure.

The described properties are confirmed by the changes in the microstructure and mineral composition. Thus Portland cement stone samples aged in Aldecol solution are characterized by the increase in the total CaO concentration in the composition of portlandite, calcite, aragonite and vaterite after one month of exposure (Table 1, Figure 6). Later, the content is reduced to some extent and further significant fluctuations do not occur.

Table 1. Mineral composition of Portland cement stone exposed in Aldecol solution, mass %.

Mineral	Period of hardening, months						
	28 days	1	2	3	4	5	6
Alite	23.69	18.3	17.7	15.8	12.7	14.0	10.9
Belite	14.1	12.1	12.1	11.9	11.8	11.1	10.5
Brownmillerite	13.21	6	4.8	3.8	3.6	2.6	2
Portlandite	24.70	40.9	35.0	32.2	30.8	27.6	17.4
Calcite	4.29	19.8	26.5	29.0	35.3	43.2	57.8
Aragonite	18.36	–	–	–	–	–	–
Vaterite	1.65	–	–	–	–	–	–
Ettringite	–	2.9	3.9	7.3	5.8	1.5	1.4

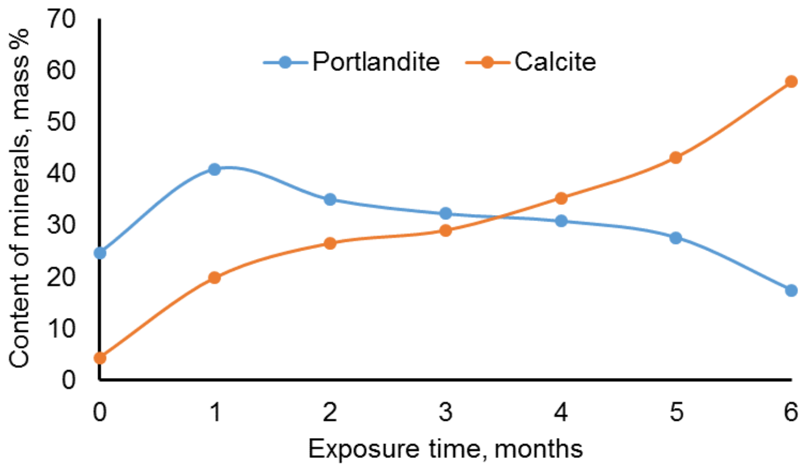

Figure 6. Dependences of Content of Portlandite and Calcite on exposure time of Portland cement samples aged in Aldecol solution.

At the same time, the increase in strength for all solutions is comparable, the maximum increase is observed after 6 months (Figure 5, a), which is characterized by the maximum concentration of calcite (Figure 6), crystallizing in pores and voids, thus filling the free space and compacting the array. In samples aged for 1 month in an Aldecol solution, sufficiently large tabular portlandite crystals reaching 60 mcm are identified (Figure 7 a). Hexagonal plates have clearly defined faces, which indicate growth structures. The crystals have cleavage, which is also confirmed by the layering of the structure for new formations (Figure 7, b). Elongated columnar crystals are typical of all samples exposed for no more than 4 months (Figure 7, c, d). They grow on the walls of the pores and grow through the tabular crystals. In samples of the exposure of 2 months and more tabular crystals continue to be found in cavities (Figure 7, b), the edges of which are covered with small new formations of later generations. The samples aged in Aldecol are characterized by the absence of elongated columnar crystals after 4 months of exposure (Figure 7, e, f).

To sum up the analysis of the microstructure of Portland cement stone samples exposed in a sanitation medium, it is necessary to note that dissolution structures are not identified in the samples. This, firstly, correlates to the kinetics of changes in strength and the change in the ratio of CaO content in portlandite and calcite, and secondly, indicates that Aldecol is not an aggressive agent and does not have a chemical effect on hydration products.

In the case of samples of aluminous cement stone, aged in a sanitation solution, the strength changes randomly. This correlates well to the data on changes in the main mineral phases of the stone (Table 2).

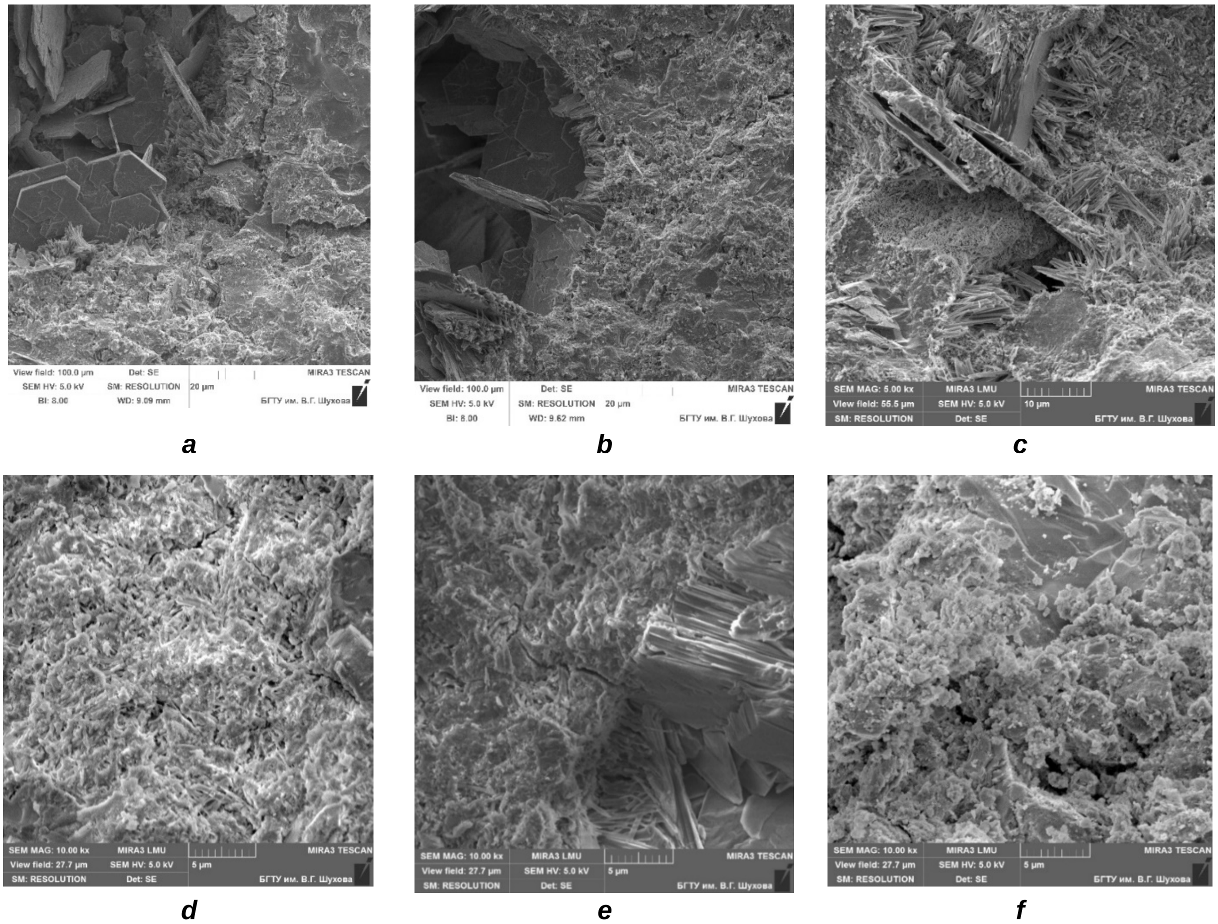

Figure 7. Microstructure of samples of Portland cement stone aged in Aldecol solution:
a – one month; b –two months; c –tree months; d – four months; e – five months; f – six months.

Table 2. Mineral composition of aluminous cement stone exposed in Aldecol solution, mass %.

Mineral	Period of hardening, months						
	28 days	1	2	3	4	5	6
CAH_{10}	28.53	35.9	13.2	34.7	33.9	33.7	24.1
C_3AH_6	0	1.6	4.5	0.0	6.4	4.0	7.3
AH_3 Hydrargillite	5.76	14.1	24.9	14.8	16.9	14.5	20.8
Akermanite – Helenite	23.01	16.1	13.9	17.0	15.2	15.8	14.8
a-C_2S	4.42	3.0	2.3	3.1	3.1	2.8	3.2
CA	3.19	2.6	4.0	3.7	3.0	2.8	3.7
Vaterite	3.22	3.4	17.1	3.6	0.0	3.8	1.7
C_4AF	12.6	9.6	9.6	8.7	8.9	8.9	7.4
Perovskite	8.02	6.8	5.5	8.3	6.7	8.0	10.8
Wollastonite 2M	11.25	6.9	5.0	6.1	5.9	5.8	6.3

Significant differences in the variation kinetics of aluminate phases, which are responsible for the strength of aluminous cement composites, were not noted in comparison with the control medium: as in the case of pure water, CAH_{10} recrystallized into stable forms C_3AH_6 and AH_3 (Figure 8).

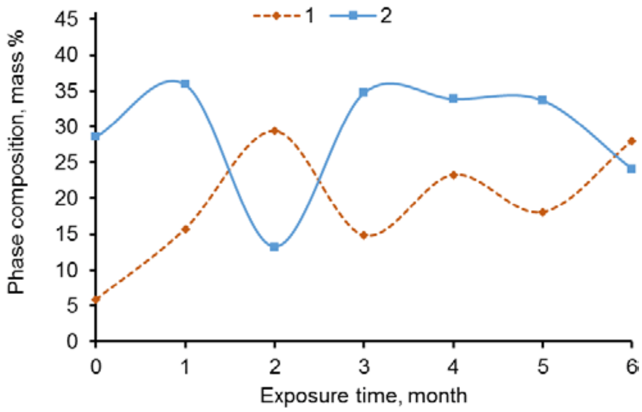

Figure 8. Dependences of phase changes C_3AH_6 + AH_3 (1) and CAH_{10} (2)
on exposure time for aluminous samples of cement stone aged in Aldecol solution.

During exposure in a sanitation agent, the concentration of carbonate compounds (vaterite) increased, which was due to the carbonization of the initially formed substance (Table 2). At the same time, its maximum value was noted after 3 months of exposure in a solution of a sanitation agent. It complied with the strength data: the strength after 3 months of exposure was two times higher than that for samples aged in water (Figure 5, b). In contact with Aldecol medium the concentration of vaterite increased, which was associated with the carbonization of calcium compounds of aldehydes (Table 2).

After 1 month of exposure in all types of solutions, the matrix of samples of aluminous cement stone was dense and composed of cryptocrystalline substance (Figure 9, a). With the increase in exposure time to 2 months, no significant changes in the microstructure were observed except decompaction and traces of dissolution (Figure 9, b). In samples exposed in Aldecol for 3 months in the zones of the pore space, new formations with atypical morphostructures for this system appeared. These were druses from intergrowths of lamellar crystals resembling “gypsum roses” (Figure 9, c). The size of individual druse reached 100 microns, the size of individual plates reached up to 30 microns. These aggregates were surrounded by fine crystalline columnar crystals not exceeding 3 microns in length. Such areas of the accumulation of idiomorphic crystals were quite often found in samples aged in Aldecol solution. After exposure for longer periods (4–6 months) in the Aldecol solution, both the structures of the formation of later generations and the structures of its dissolution were observed (Figure 9, d–f).

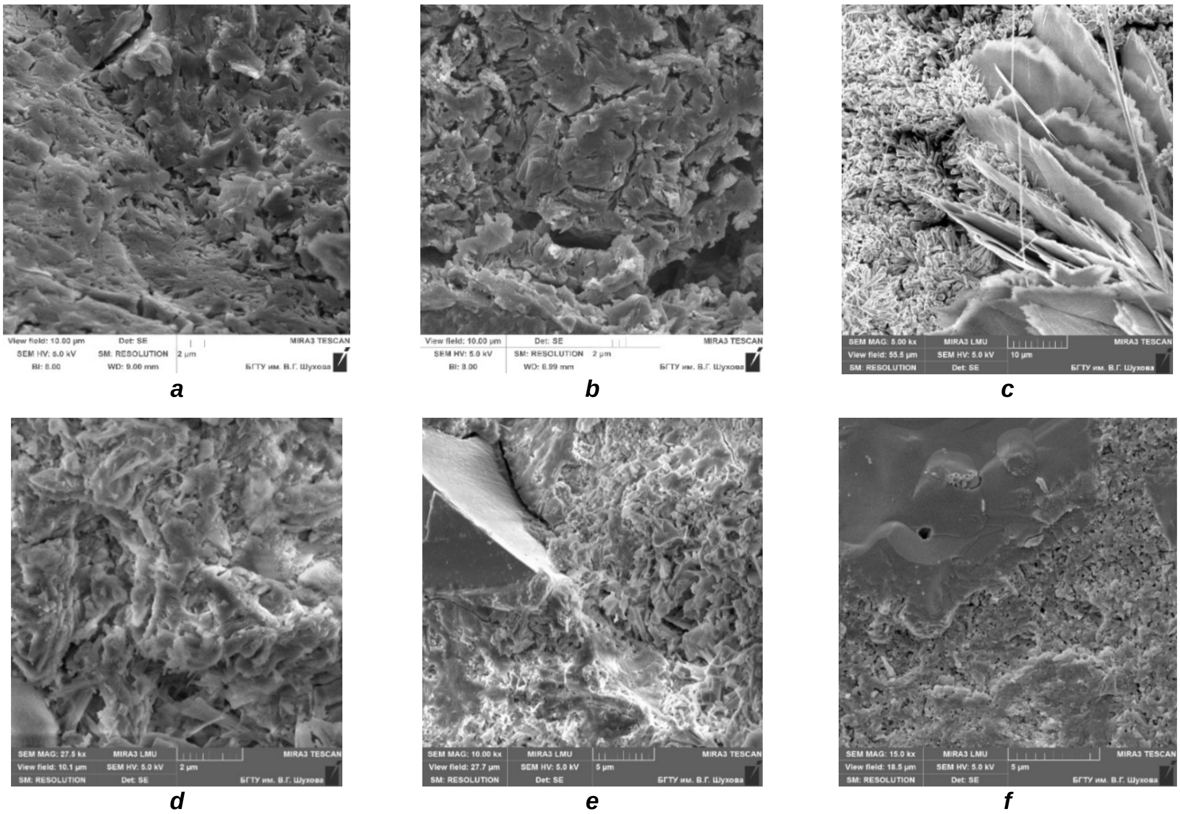

Figure 10. Microstructure of samples of aluminous cement stone aged in Aldecol solution: a –one month; b –two months; c –three months; d – four months; e – five months; f –six months.

4. Conclusion

Thus, the research showed the influence of the model environment, which was an imitation of the impact of the sanitation processing of the premises of agricultural enterprises. It was found that there was no obvious degradation effect of the sanitation solution on the cement stone.

1. The dependences of the strength of cement stone as the main indicator of the quality and resistance of the composite were established: after 6 months of exposure in sanitation solution the strength of the stone samples increased regardless of its composition.

2. For Portland cement stone, the increase in strength was 10 % compared to the samples aged in pure water, and 1.9 times compared to the original samples without exposure.

3. In the case of aluminous cement, there was a 2-times increase in strength compared to samples aged in pure water, and 1.6 times compared to the original samples without exposure.

4. It was shown that the increase in the strength of materials occurs due to the intensification of carbonization processes in the environment of sanitation product, which led to the colmatation of pores and voids due to crystallization of insoluble calcium carbonates. This was confirmed by compaction of the microstructure of cement stone, expressed by a 12 % increase in the mass of samples regardless of the type

of cement stone, as well as the increase in the total concentration of carbonate compounds in the volume of the material after 6 months of exposure.

Nevertheless, it is necessary to note that despite the obvious positive effect of the solutions of sanitation agent on the properties of cement stone, the real impact of such products during processing is probably characterized as a negative one. It is explained by the cyclical effect in terms of alternate wetting / drying of the surface of material, which will lead to the release of soluble calcium hydroxide to the surface and washing off during subsequent processing with the formation of additional porosity of products.

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Стойкость цементного камня в растворах санационных средств

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Ключевые слова: бетонная конструкция, цементы, коррозия, биодеструкция, химическая коррозия, кисллотостойкость

Аннотация. Биологическая коррозия является видом воздействия, затрагивающим практически все возможные объекты строительства, что особенно остро касается предприятий агропромышленного комплекса. К основным мероприятиям по предотвращению коррозионного процесса конструкций относятся санитарно-профилактические работы, проводимые при помощи различных химических средств (биоцидов). Концентрацию рабочих растворов для санации определяют исходя из цели дезинфекции и степени устойчивости возбудителей, при этом не учитывается их влияние на физико-механические свойства поверхности материала. Химическая обработка помещений, несмотря на очевидные плюсы, связанные с уничтожением патогенной микрофлоры, характеризуется недостатками, главным из которых является деградационное воздействие на строительный композит и, как следствие, существенное сокращение жизненного срока конструкций. Предметом исследования являлась оценка степени агрессивного воздействия санационной обработки помещений на цементный камень различного состава. В качестве объектов исследования использовались портландцемент как наиболее распространенное изученное вяжущее и глиноземистый цемент как вяжущее с начальной более высокой коррозионной стойкостью. В качестве экспериментальной среды, моделирующей воздействие санационного средства на камень при реальной эксплуатации материала в натурных условиях, использовался раствор реагента для санации. Контрольной средой выступала водопроводная вода. Оценку степени воздействия среды на цементный камень различного состава осуществляли на основании данных об основных физико-химических показателях процесса (изменение массы, водородного показателя среды, прочности на сжатие и коэффициента химической стойкости), а также фазово-структурные трансформации камня (минеральный состав, микроструктурные особенности матрицы цементного камня), выдержанного в агрессивной среде в зависимости от длительности экспонирования. Установлено отсутствие явного деградационного воздействия санационного раствора на цементный камень: отмечается рост прочности образцов после 6 месяцев экспозиции (для портландцементного камня: на 10 % по сравнению с образцами, выдержанными в чистой воде, и в 1,9 раза по сравнению с исходными образцами без выдержки; для глиноземистого цементного камня: в 2 раза по сравнению с образцами, выдержанными в чистой воде, и в 1,6 раза по сравнению с исходными образцами без выдержки) как основного показателя качества и резистивности композита и, как следствие, коэффициента химической стойкости. Рост прочности материалов происходит вследствие интенсификации карбонизационных процессов в среде санационного средства, что приводит к кольматации пор и пустот за счет кристаллизации нерастворимых карбонатов кальция. Это подтверждается уплотнением микроструктуры цементного камня, выражаемой ростом массы образцов на 12 % независимо от вида цементного камня, а также увеличением суммарной концентрации карбонатных соединений в объеме материала после 6 месяцев выдержки.

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