

Buildings and structures corrosion of metal structures and effectiveness of its prevention

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Abstract. In this article, metal structures can be partially or completely destroyed during the corrosion of building and building structures. Prepared buildings and structures, pipes, tanks, and other structural materials corrode (rust, collapse, and collapse) during operation, causing great damage to the manufacturing industry. The corrosion rate is unknown, and methods have been developed to combat corrosion.

1 Introduction

It is no secret that the types of building materials are increasing today. One of them is - metal constructions are spreading widely around the world. It can be explained in the first way that using armature or other metal devices in the construction of buildings is more economically beneficial. This not only saves money but also ensures the strength and durability of the building frame.

Chemical compounds formed due to the interaction of metal and a corrosive environment are called corrosion. Corrosion can remain on the surface of metal structures in the form of oxide films, scale, or rust. Depending on the degree of their adhesion to the metal surface, different situations are observed. For example, rust forms a loose layer on the surface of iron alloys, and the corrosion process spreads to metals and can lead to the appearance of wounds and leaks.

Decree of the President of the Republic of Uzbekistan No. PF-4947 of February 7, 2017 "On the Strategy of Actions for Further Development of the Republic of Uzbekistan", PQ-2660 of September 28, 2016 "In 2017-2021 Rural on the program for the construction of affordable housing according to updated model projects in localities", PQ-3182 dated August 8, 2017 "Priority measures to ensure rapid socio-economic development of the regions and "On measures to ensure rational use of energy resources" dated July 17, 2017 No.

The requirements of the times related to the production of metal structures are necessary to implement their tasks.

Buildings and structures made of metal and its alloys, pipes, reservoirs, and other construction materials corrode (rust, decay, disintegrate) during their operation, causing great damage to the production industry.

One of the urgent tasks is to protect buildings and structures from corrosion to maintain their working capacity and ensure reliable operation during the use of buildings and

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structures. In particular, the general pollution of the atmosphere with various corrosive-active substances and the specific characteristics of the products produced during the extraction, storage, and transportation of oil and gas products require increasing the corrosion resistance of the structures used in this field.

The type of corrosion in metals depends on the environment surrounding the metal. Chemical corrosion occurs when metals are exposed to dry gases (oxygen, sulfide anhydride, hydrogen sulfide, halogens, carbon dioxide, etc.) and non-electrolyte liquids. This is especially common in high-temperature conditions, so this type of decay is also called gas corrosion of metals. Gas corrosion is particularly damaging to metallurgy. Their surface is covered with aluminum to protect iron and steel products from gas corrosion [1-6].

2 Methods

In the construction of industrial buildings, if attention is paid to the use of new efficient building materials, prefabricated elements, the use of light, economic, large-scale, highly factory-made constructions with improved quality, the cost of construction will decrease, metal consumption will decrease, and the durability of the building will increase. The architectural expression is improved. In the design and construction of industrial buildings, special attention should be paid to solving environmental problems. Important issues such as limiting and stopping waste emission into the atmosphere, preventing noise and vibration, electric and magnetic fields, radiation, lighting workplaces, and ensuring normal temperature and air purification should always be at the center of attention [7-13].

Each stage can proceed sequentially or in parallel with the formation of corrosion on the metal surface. An oxidation reaction occurs when a metal combines with a group of atoms or molecules, loses electrons, or moves from one oxidation state to another, higher state.

A general oxidation reaction of this type can be represented as two simultaneous reactions:

- electronic oxidation;
- electron recovery;
- general reaction.

A monovalent metal forms one oxide; a multivalent metal, as a rule, can form several different oxides, the number of which is determined by the valence of the metal. Oxides are electrically neutral, have a certain crystalline structure, and consist of grains (crystals) with properties similar to those of metals.

The oxide can recrystallize, grain growth, and plastic deformation, especially at high temperatures. Constructions of buildings and structures are the most dangerous types of local corrosion for metal. This is shown by the graph of the dependence of the strength loss of duralumin on the corrosion strength loss for different corrosion damage (Fig. 2).

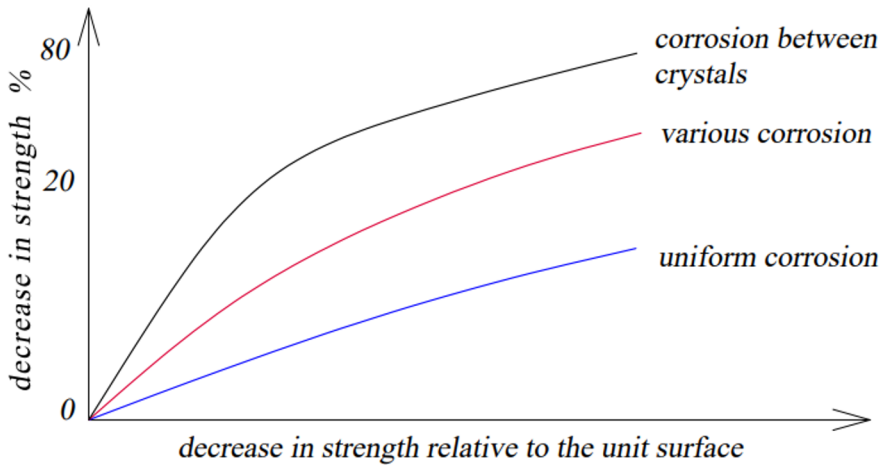


Fig. 1. Corrosion of strength loss

Corrosion Loss vs. Strength Graph Depending on the distribution of corrosion cracks, corrosion damage is usually transcrystalline when cleavage occurs along the grain body and transcrystalline when cleavage occurs along grain boundaries or intercrystalline.

During the repair period, oil, gas, and water leaks occur due to corrosion damage, the thermal conductivity of heat exchange surfaces deteriorates due to the deposition of corrosion structures, and the entire batch of small copper products introduced into the system as a result of corrosion of structural parts of buildings and structures due to rust can break. Traces of metals can change the color of paints.

The optimal problem becomes more complicated when corrosion rates are unknown, and corrosion control methods are uncertain. Corrosion level data of building and construction structures allows for a more accurate assessment of the service life of structures and facilitates the design of structures. This shows that indirect losses constitute a significant part of the total corrosion losses, but their calculation is difficult even in a single industry.

Corrosion of metals is the destruction of metals under the physical and chemical influence of the external environment. Methods of fighting against corrosion. Plasma is electrolytic sedimentation, gas corrosion, corrosion erosion, crevice corrosion, etc. All this leads to the need to protect equipment from the effects of an aggressive environment and new organic corrosion that is only adsorbed on the metal surface.

Chemical corrosion is activated at high temperatures. The susceptibility of metals to chemical oxidation is determined by their ability to participate in oxidation-reduction reactions and the value of the oxygen potential.

Electrochemical corrosion is a more complex type of corrosion; in this case, the corrosion of the metal occurs with the combined effect of water and soil on the steel surface (for example, underground foundations). Moist soil is a slightly alkaline environment that promotes the formation and movement of stray electrical currents in the soil. They are the result of the ionization of metal particles in an oxygen-containing environment and begin to transfer metal cations from the surface to the outside. The fight against such corrosion is complicated by the fact that it is not possible to diagnose the condition of the soil in the place where the steel connection is laid.

What type of corrosion occurs in metals depends on the environment surrounding the metal. Chemical corrosion occurs when metals are exposed to dry gases (oxygen, sulfide

anhydride, hydrogen sulfide, halogens, carbon dioxide, etc.), and non-electrolyte liquids. This is especially common in high-temperature conditions, so this type of decay is also called gas corrosion of metals. Gas corrosion is particularly damaging to metallurgy. To protect iron and steel products from gas corrosion, their surface is covered with aluminum.

Corrosion processes are the most real threat to metal structures. Regardless of the thickness of the steel, rust can quickly render the material unusable. In some cases, with minor damage, the development of corrosion can be stopped and its consequences eliminated. Often, you need to completely replace the metal elements. Therefore, the protection of steel against corrosion is the first priority in constructing and using structures.

Causes and consequences of metal corrosion Under ideal conditions, any metal retains its properties for a long time. Although the composition of the material does not contain additional compounds, the absence of external influences allows for maintaining the strength and rigidity of the structure. It is almost impossible to achieve such conditions in real life. Corrosion processes can occur for the following reasons:

- an increase in air humidity, as a result of which the metal is constantly exposed to significant loads and begins to oxidize very quickly;

- precipitation on the unprotected steel surface also leads to the spread of corrosion centers;

- most of the time, the cause of metal oxidation is stray currents on the surface of the product;

- an atmosphere with different amounts of reactive elements can also increase the corrosion rate.

Electrochemical corrosion occurs when the contact devices of power lines are oxidized as the gaps between the elements of the electric circuit increase. In addition to their destruction, in this case, the power consumption of devices increases dramatically.

3 Results and Discussion

Constructions of buildings and structures of this type operating at high temperatures and pressures are subject to this type of metalworking. Cutters, etc., cannot be coated against corrosion, as high surface integrity is required from the part. At the same time, in high-speed cutting, cold pressing, and other energy-intensive metal processing, mechanochemical reactions begin, the intensity of which increases with the temperature increase at the contact surface of the processed part with the structures of buildings and structures. The surface of the metal can be protected by painting it or applying surface films that are neutral to oxygen. Coloring is used in everyday life and in the processing of relatively large areas (mainly underground pipes). Among the most resistant paints are enamels and paints that contain aluminum [14, 15].



Fig. 2. Temperature and moisture effects on metal works

We can determine the force generated in a metal structure by the following formula:

$$N = \sum P_{ni} \cdot N_i \cdot \gamma_{pi} \cdot \gamma_n \cdot \Psi$$

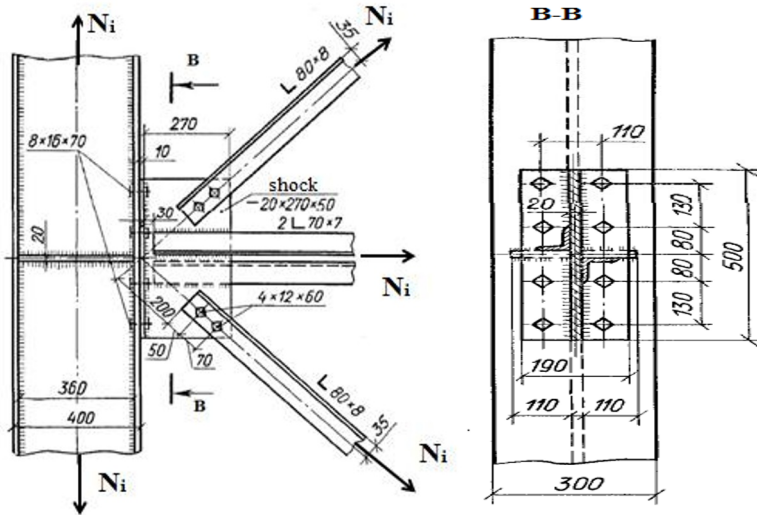


Fig. 3. Resulting Force in Metall Struktur

N_i is force (longitudinal); $P_{ni} = 1$ is the force generated in the element when equal to γ_{pi} is load reliability coefficient; γ_n is reliability coefficient according to the function of the building; Ψ is coefficient that takes into account the combined effect of loads.

The load-bearing capacity of a metal structure can be determined depending on its surface and the resistance of the material:

$$S = A_n \cdot R_{\gamma n} \cdot \gamma_s$$

A_n is element cross-section (netto) surface; $R_{\gamma n}$ is calculated yield strength of element material; γ_s is the coefficient that takes into account the working conditions [12, 13]. The heat resistance of the metal is not great. When the temperature approaches 250°C, the modulus of elasticity of steel begins to decrease, and at 600°C, it becomes completely plastic. To meet fire safety requirements, it is necessary to increase the fire resistance of metal structures. Various protection methods can be used for this.

The resulting iron oxide Fe_2O_3 is distinguished by an increase in strength and therefore begins to intensively destroy the surface of structures.

The choice of a suitable surface protection method against the formation of rust is determined by the operating conditions of a particular part or structure. The following methods are the most effective:

- Application of surface weather-resistant coatings;
- Metallization;
- Metal alloy with elements more resistant to participation in oxidation-reduction reactions;
- Changes in the chemical composition of the environment.

The surface of the metal can be protected by painting it or applying surface films that are

neutral to oxygen [14, 15].

In the first case, the effect is achieved by blocking the access of oxygen to the steel surface; in the second case, it is achieved by applying aluminum to the surface, which is a chemically inert metal that protects the steel from corrosion damage.

One of the main issues is the study of the formation mechanism of the fire-resistant coking coke layer, its thermal-physical and physical-mechanical properties, and its stability under the influence of fire. Figure 4 shows a simplified diagram of the formation of a coking layer of a polymer composite based on an acrylic polymer [16].

The stages of formation of the expanded coke layer of fire-protective expandable polymer composite coatings are as follows: endothermic and exothermic reactions of phosphorus, nitrogen-containing flame retardant, and expandable chemical components; the formation of a coking coke layer by reacting the coking polymer components with each other under the influence of temperature; under the influence of high temperature, the formation of coke flows and the formation of its mechanical properties.

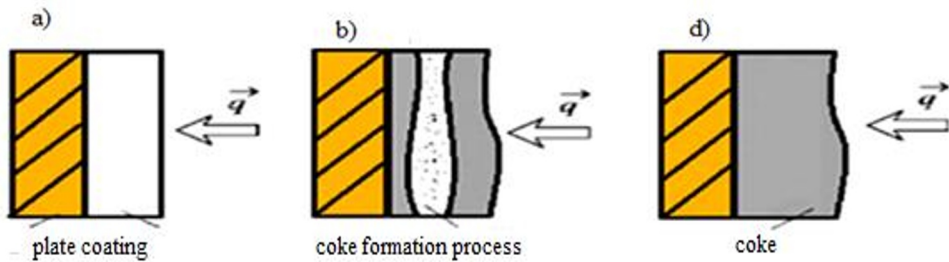


Fig. 4. What is stage of production of polymer composites: a is plate covered with fire-resistant paint polymer composite; b is what kind of process; d is finish of final coking after final coating.

This protection method's positive features are its ease of implementation and relatively low financial costs since the process is very simply mechanized. At the same time, the durability of this protection method is not great because of the lack of a high degree of affinity with the base metal; such coatings begin to collapse mechanically after some time. [14, 15]

The proposed corrugated coatings are one of the effective methods widely used today as preventive measures for the fire protection of metal structures. They aim to reduce losses in the event of a fire in buildings and structures. Due to the bulging of coatings, a heat-protective layer, i.e., coke, is formed at high temperatures. It has been proven through experimental tests that the fire protection coatings of metal structures can provide several times more heat protection, the fire resistance limit of metal structures increases from 7 to 1, and they do not lose their load-bearing capacity for a long time.

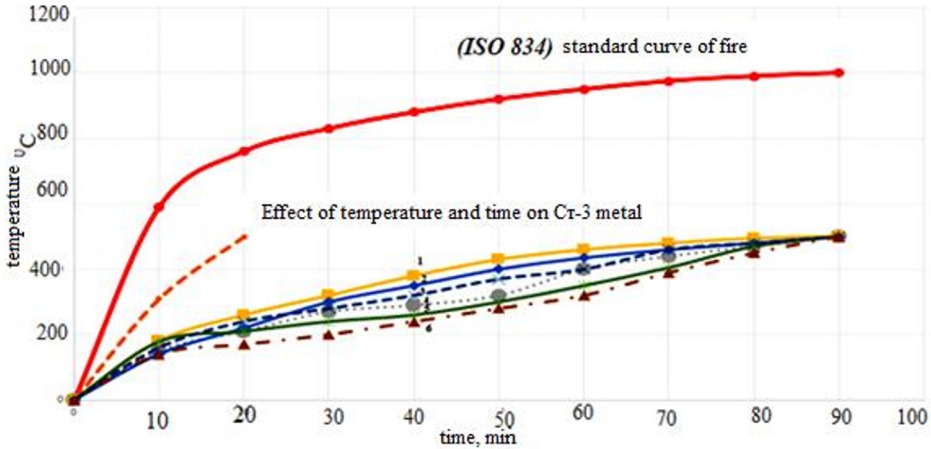


Fig. 5. 1 - Based on acrylic copolymers ((1) E-21-1, (2) E-21-2, (3) E-21-3 and (4) comparison of rate of heat exposure of metal plates treated with E-21-4 brands) fire-protective intumescent coatings and analogs ((5) Metallaks, (6) Stabiterm), and untreated metal plates.

Table 1. The effect of fire-protective foam coatings based on acrylic copolymers and analogs on the rate of heat exposure of metal plates [19]

The name of the corrugated coating	Time dependence of the rate of heat action (minutes)									
	10	20	30	40	50	60	70	80	90	
1 E-21-1	190°C	240°C	300°C	390°C	410°C	450°C	460°C	485°C	500°C	
2 E-21-2	150°C	220°C	270°C	350°C	400°C	440°C	450°C	480°C	500°C	
3 E-21-3	170°C	235°C	260°C	320°C	360°C	410°C	450°C	480°C	500°C	
4 E-21-4	160°C	220°C	240°C	280°C	320°C	400°C	440°C	470°C	500°C	
5 Metallaks	190°C	210°C	240°C	260°C	290°C	370°C	400°C	470°C	500°C	
6 Stabiterm	130°C	160°C	200°C	240°C	280°C	320°C	390°C	450°C	500°C	

Fire-protective convex coatings based on acrylic copolymers and analogs metals, stabitherm-treated metal plates, and untreated metal plates were compared [20].

The proposed coatings are one of the effective methods widely used today as preventative measures for the fire protection of metal structures. They aim to reduce losses in the event of a fire in buildings and structures. The coatings form a heat-protective layer at high temperatures, i.e., coke. It has been proven through experimental tests that fire protection coatings for metal structures can provide several times more heat protection, the fire resistance limit of metal structures increases from 7 to 1, and they do not lose their load-bearing capacity for a long time [3].

In this case, corrosion protection occurs due to the formation of a chemical film consisting of components resistant to oxygen, pressure, temperature, and moisture on the surface of the treated metal. For example, carbon steels are treated with phosphating. The process can be carried out both cold and hot, forming a layer of phosphate salts of manganese and zinc on the metal surface. An analog of phosphating is oxalate - the process of treating the metal with oxalic acid salts. The use of such technologies increases the resistance of metals to tribochemical corrosion. The application of these methods is laborious and complex and requires special equipment. It also changes the color of the final surface, which is not always acceptable for aesthetic reasons [4].

Unlike the previous methods of alloying and metallization, the end result is a metal layer chemically inert to oxygen. Such metals include metals located as far as possible from

hydrogen in the oxygen activity band.

The simplest and most common method of surface metal treatment is steel treatment. The structure is painted with enamel and paints with a high aluminum content. As a result, the access of ambient air to the metal is completely blocked. The simplicity and cheapness of the technology are its main advantages. The disadvantages include the fragility of the coating and the need to periodically renew it.

4 Conclusions

Experimental tests were prepared based on the standard requirements of GOST 9.506-87. According to him, the experience is for testing Samples of E-44-2, E-44-3, E-21-1, and E-21-3 polymer composite coatings were prepared for experiments. The experimental process was carried out for 50 days at a temperature of 25 1oC on a sample of St3 metal in various highly corrosive chemical solutions. Results of experimental tests of metal structures

Table 2 shows that they have a good result compared to the FLAMER® EP analog.

Table 2. Determining degree of corrosion protection of anticorrosive polymer composite coatings by gravimetric method

Materials taken for the experiment	indicators	Sample for review	E-44-2	E-44-3	E-21-1	E-21-3
H ₂ O	K	0.0012	0.000003	0.000002	0.000003	0.000002
	Z	-	99.7	99.8	99.7	99.8
NaCl 5%	K	0.0059	0.000069	0.000007	0.000061	0.000058
	Z	-	98.8	99.8	98.9	99
Na ₂ CO ₃ 5%	K	0.0061	0.00060	0.000058	0.000080	0.000061
	Z	-	90.2	99.1	98.6	99
Na ₂ SO ₄ 5%	K	0.0049	0.000061	0.000058	0.000061	0.000048
	Z	-	98.7	98.8	98.7	99
Na ₂ S 5%	K	0.0060	0.00031	0.000074	0.000077	0.000058
	Z	-	94.8	98.7	98.6	99
NHCO ₃ 5%	K	0.0057	0.000058	0.000058	0.000058	0.000007
	Z	-	99.8	99.8	99.8	99.8
CaCO ₃ 5%	K	0.0029	0.000030	0.000028	0.000034	0.000006
	Z	-	98.9	99	98.8	99.7

Note: K, (g/cm² milk) is corrosion rate; Z % is level of protection.

The results show that these coatings provide high corrosion protection for metal structures and reinforced concrete.

Scanning electron microscope and element analysis of metal constructions and polymer composite coatings revealed that the chemical composition of the polymer composite formed a good mixture. Based on the results of the SEM analysis, it can be concluded that polymer composite coatings made by adding flame retardants, chemical additives, and minerals that increase temperature stability to the matrix of polymers show superior results compared to analogs.

The difference in the technologies for obtaining such anti-corrosion layers is in the method of their application. In the metallization process, an ionized arc current of finely dispersed metal is directed to the surface, and the alloy is formed in the process of melting

the metal as a result of metallurgical reactions between the base metal and the introduced alloying additives.

References

1. Di Sarno, L., Majidian, A., & Karagiannakis, G. The effect of atmospheric corrosion on steel structures: A state-of-the-art and case-study. *Buildings*, 11(12), 571. (2021).
2. Bertolini, L., Elsener, B., Pedferri, P., Redaelli, E., & Polder, R. B. *Corrosion of steel in concrete: prevention, diagnosis, repair*. John Wiley & Sons. (2013).
3. Korolov, V., Filatov, Y., Magunova, N., & Korolov, P. Management of the quality of corrosion protection of structural steel based on corrosion risk level. *Journal of Materials Science and Engineering*. B, 3(11B). (2013).
4. Di Sarno, L., Majidian, A., & Karagiannakis, G. The Effect of Atmospheric Corrosion on Steel Structures: A State-of-the-Art and Case-Study. *Buildings* 2021, 11, 571. (2021).
5. Hu, J. Y., Zhang, S. S., Chen, E., & Li, W. G. A review on corrosion detection and protection of existing reinforced concrete (RC) structures. *Construction and Building Materials*, 325, 126718. (2022).
6. T. Khankelov, Z. Maksudov, N. Mukhamedova and Shavkat Tursunov. Crushing and screening complex for the production of compost from organic components of municipal solid waste. In *E3S Web Conf*. Vol. 264, (2021).
7. Aldoshin, N., Mamatov, F., Ismailov, I., Ergashov, G. Development of combined tillage tool for melon cultivation. In *19th international scientific conference engineering for rural development Proceedings*, Jelgava, Vol. 19. (2020).
8. Aldoshin N.V., Mamatov F.M., Kuznetsov Yu.A., Kravchenko I.N., Kuprenko A.I., Ismailov I.I., Kalashnikova L.V. Loosening and leveling device for preparing soil for melon, *INMATEH - Agricultural Engineering*, Vol. 64, (2021).
9. Negmatov S.S., Abed N.S., Gulyamov G., Eshkobilov O.Kh. Features of contact interaction of composite polymer materials with raw cotton in the process of friction. *IOP Conference Series: Materials Science and Engineering*, Vol. 1030, (2020).
10. Abed N.S., Gulyamov G., Tuhtasheva M.N., Eshkobilov O.Kh. Engineering composite materials for the cotton processing industry. In *E3S Web of Conferences* Vol. 264, (2021).
11. Gulyamov G., Eshkobilov O.Kh. Composite polypropylene polymer materials that work in contact with raw cotton. In *E3S Web of Conferences* 264, 05055 (2021).
12. Eshqobilov O.Kh., Tukhtasheva M.N. Investigation of antifriction properties of composite epoxy material in interaction with raw cotton. *International Journal of Mechatronics and Applied Mechanics*, Vol. 12. pp. 134–139. (2022).
13. Eshkobilov O.Kh. Investigation of the contact interaction of the working bodies of machines with raw cotton. *E3S Web of Conferences* Vol. 365, 04001, (2023).
14. Eshkobilov O.Kh., Negmatov S.S., Abed N.S., Gulyamov G., Investigation of the Process of Electrification of Composite Polymer Coatings in the Case of Frictional Interaction with the Fibrous Mass. *AIP Conference Proceedings* 2432, 050009, (2021).
15. Eshqobilov O.Kh., Tukhtasheva M.N. Development of a disc tribometer and determination of its optimal parameters and modes of contact interaction of composites with raw cotton. *International Journal of Mechatronics and Applied Mechanics*, Issue 10. pp. 214–221. (2021).