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# CORROSION OF METAL CONSTRUCTION STRUCTURES

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**ABSTRACT**

*The paper considers the main types of corrosion taking into account the direction of corrosion processes. The main parameters of metal building structures corrosion and factors that have a significant influence on these parameters are taken into account, which can influence the increase of such structures longevity. One of the main factors of corrosion rate determining is the humidity of air and dust deposited on surface from atmosphere at production emissions.*

**Key words:** Materials, Construction, Corrosion, Aggressive Medium, Quality.

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## 1. INTRODUCTION

Loss of material and strength of structural members due to corrosion can have severe consequences in terms of finance, safety, and convenience. Metal corrosion is considered one of the most dangerous types of building structures destruction [1, 2]. Therefore, protection of building structures from corrosion is a very topical topic of research, where it is important to decide the correct choice of material for building structures [3-5].

The market offers a wide range of different building materials [6].

Nevertheless, most often it is metals used for the main load-bearing and roofing structures [7, 8]. The metal structures choice is determined by their technical advantages: greater precision of manufacture, simplicity and accuracy of assembly on high-strength bolts, which makes them more advantageous, for example, compared with reinforced concrete structures [9]. However, the lack of the steel bearing structures remains use the need for expensive and labor-intensive anti-corrosion and fire protection measures, warming and finishing [10, 11]. That is, to select a brand of metals, it is necessary to analyze their properties and their susceptibility to corrosion.

# 2. MATERIALS AND METHODS

## 2.1. Related work

A number of works are devoted to building constructions from metals. Along with the design, erection and operation of numerous metal building structures, it has been and remains an important task to prevent corrosion of metal building structures.

The environment impact of Phase Change Materials (PCMs), incorporated in building envelopes, is investigated in [12]. This study presents some significant findings regarding the application of Life Cycle Assessment (LCA) to PCM-incorporated building systems. In particular it has been shown that there is consistency among the findings of the studies; however the findings were found to depend on the goal and scope of definition for each LCA. Additionally, taking into consideration all the life-cycle phases of PCM-incorporated building constructions, they were found to be more environment- friendly compared to other conventional thermal insulating materials.

Durability of building materials and components is described in [13].

Corrosion effects in the structural design of metal fasteners for timber construction are presented in [14].

A study of the mechanical response of corroded reinforcement subjected to monotonic and cyclic loads by means of an experimental study is presented in [15]. More than 180 corroded specimens, 40 monotonic and 140 fatigue tests were performed. Relationships between corrosion penetration and the mechanical properties of reinforcing steel bars were identified. In addition, a study of the influence of the pit geometry on the fatigue life was carried out. A severe non-linear reduction in the mechanical properties studied, related to the corrosion degree was observed.

In [16] insights into the use of metal-organic framework as high performance anti-corrosion coatings.

A new corrosion prediction model incorporating the effects of multiple dynamic environmental factors is proposed in [17]. The effects of relative humidity, temperature, sulphur dioxide, and chlorides on the short-term corrosion behavior in the dynamic environment had been studied.

## 2.2. Metals for Building Structures

The metals from which building structures are built have a significant influence on the durability of these structures, and hence on the corrosion resistance [18].

Such metals differ in composition, structure, chemical, physical and mechanical properties and application. Metals for building structures (MBS) include: steel, cast iron, zinc, aluminum, nickel. Virtually all steel structures need protection. The increased content of copper (up to 0.2%) and carbon significantly increases corrosion resistance, and in the presence of phosphorus, chromium and nickel additives, this increase is even more significant. Such steels, in addition to corrosion resistance, have increased reliability of operation at low temperatures and shock loads. It is forbidden to use nickel-free grades of 09G2 and 14G2 steels for medium- and heavily aggressive environment. Also, the use of galvanized steel or metal protective coatings for buildings and structures affected by liquid environment or ground with the concentration of hydrogen ions (pH) to 3 (acidic) and above 11 (alkaline), various solutions of heavy metal salts, alkali, calcined salt, if without the presence of their environment refers to the environment -aggressive or highly aggressive [19].

## 2.3. Corrosion of metal building structures taking into account the direction of corrosion processes

All corrosive processes start from the metal surface and propagate deep into the material [19].

Often, the metals corrosive processes are classified according to the mechanism of metals interaction with external environment; by corrosive environment form and process conditions; by corrosion damage nature; by additional influences types that metal undergoes simultaneously with the corrosive environment action [2].

Atmospheric corrosion is a complex process that depends on the interactions of multiple environmental factors like relative humidity, temperature, pollutants and wind.

Consider the corrosion process of MBS taking into account direction (mechanism) of corrosion processes. Underground (soil) corrosion mainly occurs in humid soils. Atmospheric corrosion can be divided into three types (not including crevice corrosion): dry (occurs at low humidity and is characteristic during the first period of structures operation), moist (flows at relative humidity less than 100% under invisible moisture film) and wet (with direct moistening of the metal surface by atmospheric precipitation or industrial emissions) atmospheric corrosion [1, 20]. Quantitative indicators of corrosion wear are determined, basically, value of the specific surface contact with atmosphere [20].

$$a = \frac{P}{A}, \tag{1}$$

Where a – value of specific surface contact; P – perimeter; A – cross-sectional area of structural element.

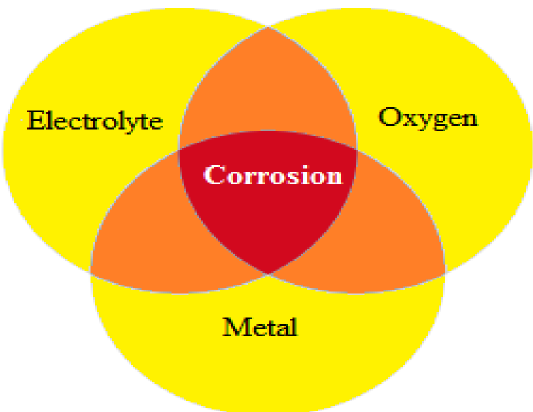



**Figure 1** Conditions for reaction of atmospheric corrosion

Of all the species, the most damaging is wet corrosion, most steel structures exposed to aggressive components (corrosive gases and corrosive dust) are exposed to it. The conditions for the reaction of atmospheric corrosion are shown in Figure 1.

Contact corrosion of metal occurs when two metals contact with different potentials in presence of electrolyte. Such corrosion occurs because of difference in electrode potential of chemical elements of the materials. The electrode potential $E_0$ is given in Table 1 [3, 20].

**Table 1** The electrode potential values $E_0$

| Material | Li | Ba | Mg | Al | Mn | Zn | Cr | Fe | Cd | Tl | Co | Ni | Sn | Pb | H | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Potential, V | -3.04 | -2.9 | from -1.18 to -2.37 | -1.68 | from -1.18 to -1.19 | -0.76 | -0.74 | from -0.41 to -0.44 | -0.4 | -0.34 | -0.28 | -0.23 | -0.14 | -0.13 | 0 | 0.15 |

The lower metals activity, less corrosion resistance.

Typically, the corrosion resistance is evaluated according to the scale presented in Table 2 [21, 22].

**Table 2** Scale of metals corrosion resistance

| Resistance group | Completely persistent | Extremely persistent | | Persistent | | Reduced persistent | | Low-resistant | | Nestling |
|---|---|---|---|---|---|---|---|---|---|---|
| Corrosion rate, mm / year | Less 0,001 | 0.001 – 0.005 | 0.005 – 0.01 | 0.01 - 0.05 | 0.05 – 0.1 | 0.1 – 0.5 | 0.5 - 1 | 1 - 5 | 5 - 10 | Over 10 |
| Score | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

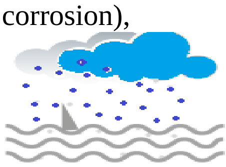
# 3. RESULTS AND DISCUSSION

## 3.1. Analysis of metal building structures corrosion features

The complex interrelationship of environment factors lead to the fact that this or that type of corrosion, with a different combination of factors, can act not only with varying intensity, but even change the direction of action on metal building structures corrosion. Thus, in one case factors "combination" can accelerate, and in the other, inhibit the corrosion process.

In general, MBS are subject to: underground, atmospheric and contact corrosion. As a result of research, affected area and main factors affecting corrosion have been determined, as well as the general protection principles, as shown in Table 3.

**Table 3** Area of damage and main factors affecting corrosion of MBS

| Corrosion name | Injury area | Factors | Protection |
|---|---|---|---|
| Underground (soil) | Observed in products and structures of underground and underwater structures. Example - rods, building supports. | Humidity, aeration, porosity, concentration of hydrogen ions (pH), dissolved salts (if any), electrical conductivity. | Zinc coating, powder coating, metal alloying, waterproofing mastic, etc. |
| Atmospheric corrosion | Observed in products and structures such as metal roofing buildings, fasteners, steel rods, vertical connections. | Sulfur Dioxide,  Chlorides (high salt content in the air markedly accelerates corrosion),  Ambient temperature, Humidity  | Painting, protective lubrication, priming, galvanizing, etc. |
| Contact corrosion | There are observed in structures such as vertical bonds, fasteners, etc. | Duration of contact, load on structures / products. | Correct contacting metals selection; introduction of insulating pads between heterogeneous metal structures; application of paint, and sometimes metal coatings; introduction of inhibitors into the solution (in case of closed systems). The contact of aluminum with copper, nickel, and steel is inadmissible, but it is possible with zinc, cadmium. |

Further, let us consider the influence of these factors on the main corrosion indicators. The main parameters include:

- Deep corrosion rate, which depends on the metals corrosion resistance;

- Corrosion rate, which depends on: environment characteristics (humidity, temperature aggressiveness); metal characteristics itself; constructive factors;
- Corrosion intensity, which depends on: nature of metal surface treatment, presence of microorganisms, changes/fluctuations in temperature and humidity on metal contact surface is additionally affected by tensile stresses, as well as chemically aggressive environment.

Chromates, silicates, hydroxyl ions, on contrary, reduce the corrosion processes intensity, promoting the formation of protective films on metal.

## 3.2. Investigation of basic metal building structures properties

In general, for each specific application, it is necessary to choose a MBS brand that would maintain stability and not be corroded under appropriate environmental conditions.

In the process of analyzing the properties of the main MBS, it is determined that:

1. Steel with addition of at least 10% chromium is called stainless steel. Addition of chromium leads to the formation of a stable and very thin (several nanometers) oxide layer (passivation layer) on metal surface. Therefore, stainless steel is not corroded, and there are no stains on contact with water, unlike carbon steel.

However, under certain circumstances, the passivation layer may collapse, leading to a local corrosion form, for example, point corrosion.

2. Aluminum alloys, when properly used, are an ideal material and almost all elements of building structures can be made of aluminum.

Let's start with a generalized assessment of materials stability in main corrosion types (Table 4), since there are a number of factors that affect corrosion, and there are many MBS brands for each type of material.

**Table 4** Generalized assessment of MBS stability

| Corrosion type | Carbon steel | Stainless steel | Al | Cr | Ni | Zn | Cu |
|---|---|---|---|---|---|---|---|
| Soil | 2 | 3 | 3 | 2 | 1 | 3 | 1 |
| Atmospheric | 2 | 3 | 2 | 3 | 2 | 2 | 1 |

The notation in Table 4: 1 – low material resistance; 2 – good stability; 3 – high stability.

Next, consider contact corrosion. Since when designing building structures from dissimilar metals for operation in corrosive environments, it is necessary to provide for measures to prevent contact corrosion in contact zones of dissimilar metals. Taking into account the data of Table 1, Table 2 and Table 4, it is expedient to present the distribution of MBS in 5 groups, taking into account the degree of their contact in the form of a pyramidal diagram (Figure 2).

The standard case of contact corrosion is shown in Figure 3. In the compound shown in Figure 3 uses galvanized carbon steel (washer) and stainless steel (screw and detail). The surface area of the more noble metal (stainless steel) is larger, which results in the severe corrosion of the washer.

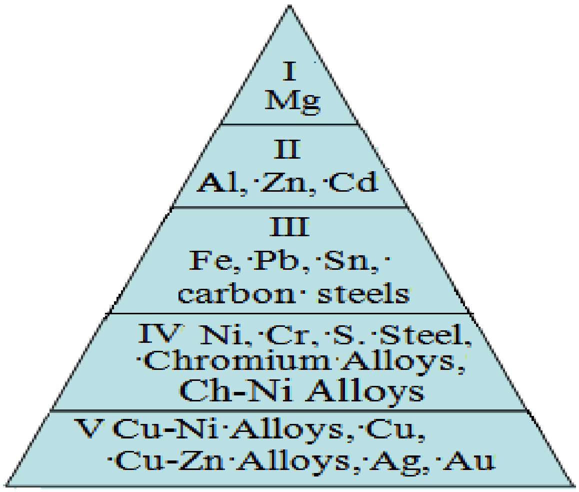



**Figure 2** Distribution of MBS by groups, taking into account the contact degree

**Figure 3** Standard case of contact corrosion

Let us compare the electrode potentials MBS, shown in Figure 2 as data in Table 5.

**Table 5** MBS electrode potentials in neutral solutions

| Mg | Al | Zn | Cd | Fe | Pb | Sn | Cu |
|---|---|---|---|---|---|---|---|
| -1,51 | -0,64 | -1,09 | -0,73 | -0,55 | -0,51 | -0,47 | -0,22 |

The comparing results of the MBS electrode potentials are shown in Figure 4.

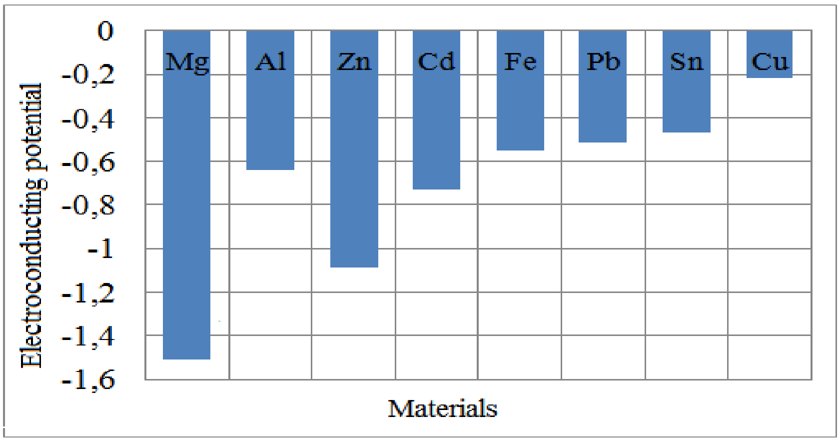



**Figure 4** Comparison results of MBS electrode potentials

The metals of each subsequent group intensify the corrosion of the metals of the previous group. Although corrosion can be within the same group. Corrosion is likely to result in contacts involving Mg alloys. It is determined that only Al, Zn and Sn are protected by good organic coatings, do not cause enhanced corrosion of Mg alloys.

Next, we investigate one of the main corrosion parameters – speed for the main MBS under three conditions:

1 – in an aggressive environment at temperatures from normal to the boiling point;

2 – in an aggressive environment at a 120°C temperature and a 4 atm. pressure;

3 – in an aggressive medium and in a solution with a 12.5% concentration at a 25°C temperature.

The corrosion rate value is shown in Table 6.

The study results are shown in Figure 5.

**Table 6** MBS electrode potentials in neutral solutions

| Environmental conditions | Al | Zn | Fe | Pb | Sn | Cu |
|---|---|---|---|---|---|---|
| 1 | 0,11 | 0,11 | 0,11 | 0,08 | 0,12 | 0,008 |
| 2 | 1,08 | 1,18 | 1,12 | 0,78 | 1,20 | 0,98 |
| 3 | 3,24 | 3,42 | 3,37 | 2,34 | 3,44 | 2,95 |

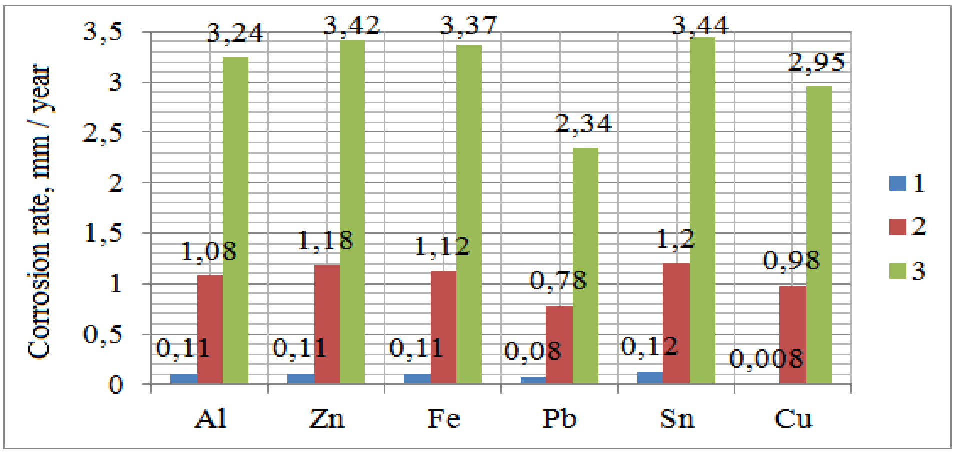



**Figure 5** Results of corrosion rate comparison for main MBS

From Figure 5 that under different conditions of an aggressive environment, Fe and Zn undergo the fastest corrosion, but nature of atmospheric corrosion development in time is significantly different. The rate of zinc corrosion as the layer of corrosion products is formed first decreases in time, and then remains constant. For iron in the initial period of corrosion, the speed is low, but in the future it increases.

## 4. CONCLUSIONS

The metal building structures corrosion with regard to the direction of flow are considers, as a result, it is determined that multicomponent alloy steels containing additives of chromium, nickel and copper, as well as silicic-manganese steels possess the greatest resistance to atmospheric corrosion.

The paper suggests a generalized classification of the main factors (temperature, humidity, environment state) that affect MBS corrosion, taking into account the direction of material corrosion.

As a result of conducted studies, it was determined that aluminum alloys resistance is higher than that of steels, and steels corrosion resistance depends more on chemical composition of these materials.

The paper identifies the main corrosion parameters of MBS and factors that have a significant effect on these parameters. One of the main factors determining the rate of corrosion is air humidity and dust, which is deposited on the surface from the atmosphere at production emissions.

Humidity, in which corrosion process is most intense, is called critical, it is estimated at 70%.

The paper presents a pyramidal diagram of MBS distribution in 5 groups, taking into account degree of contact between different metals. A comparison of electrode potentials of MBS for selected metals is given. As a result, it is determined that the lowest in copper, which means that it has less corrosion resistance.

One of the main corrosion parameters – speed (for main MBS) under three conditions was investigated. It is determined that nature of atmospheric corrosion development in time is markedly different, and lead is the most stable.

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