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LONG-TERM PREDICTIONS OF CORROSION RATE IN THE INDUSTRIAL AGGRESSIVE ENVIRONMENT IN BOR

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Abstract

General corrosion testing is carried out in the field, in selected atmospheric corrosion station, near the Sulphuric Acid Plant in Bor, for six months. To assess the corrosion resistance of steel S235JR, the analysis of mass loss after exposure to the aggressive environments in Bor were employed. In order to obtain a complete characterization of the atmosphere, as well as of the exposure condition, the meteorological data in the period of the experiment duration in the outdoor conditions were analyzed to determinate the corrosivity category. Pollution by SO_2 alone was considered in this study because this is the most common and important corrosive agent. Corrosion loss of the experimental specimens were measured. With the help of a quantitative analysis of the test result, a better determining the corrosion category can be done that represents the actual environment.

***Keywords**: corrosivity category, corrosion rate, industrial environment, accelerated corrosion test*

1. INTRODUCTION

Corrosion causes an enormous damage to the building structures, which has stimulated a large number of long-term researches. The results obtained in all researches are systematized in order to define an applicable standard, which not only classifies the corrosivity categories, but also defines the procedures and guidelines for obtaining the corrosion rate for a long-term exposed steel structures.

The standard classification system is quite simple and applicable in everyday engineering practice. The method of determining and assessing the corrosivity category of a given location and relationships between them are shown in the ISO international standard [1, 2]. It is necessary to distinguish between the determination of the corrosion rate and assessment the corrosivity in accordance with the information about the environment (atmospheric effects).

The corrosion test models, defined according to the recommendations of current standards, are used to interpolate the corrosion test data and predict the long-term behavior of steel on the basis of the short-term tests, but also to determine the corrosivity category of the observed environment.

2. EXPERIMENTAL MATERIAL AND METHODS

2.1 Assessment and Monitoring of Environmental Corrosiveness

During the evaluation of the corrosivity category, the environment being evaluated is compared to the standard industrial environment from Table 1.

Table 1. *Atmospheric corrosivity categories according to ISO 9224 [2] and corrosion rate r_{corr} for the first year exposure to the industrial environment according to ISO 9223 [1]*

Corrosivity category	Typical industrial environments		Corrosion rate of steel	
	Outdoor	Indoor	Unit	Carbon steel
C3 Medium	Industrial and urban atmosphere with an average value of sulfur dioxide pollution.	Production facilities with high humidity and a certain degree of air pollution	$g/(m^2 \cdot a)$ μm/a	$200 \leq r_{corr} \leq 400$ $25 \leq er_{corr} \leq 50$
C4 High	Industrial atmosphere	Chemical factories	$g/(m^2 \cdot a)$ μm/a	$400 \leq r_{corr} \leq 650$ $50 \leq r_{corr} \leq 80$

2.2 Long-Term Corrosion Rate Predictions

Specific calculation models are given in ISO 9224. The long-term predictions of the metal corrosion losses (C) follow the kinetic relationship for most of the experimental atmospheric corrosion data [2]:

$$\mathrm{C} = r_{corr} t^{b} \qquad (1)$$

Equation (1) is used to describe the corrosion effects obtained in tests with various duration, in various location, where C is the corrosion rate after t years, r_{corr} is that in the first year of exposure in grams per square meter per year ($\mathrm{g}/(\mathrm{m}^2\mathrm{a})$ or micrometer per year ($\mu\mathrm{m}/\mathrm{a}$), and b is an exponent, representing a function of the type of atmosphere where the steel is exposed. It should also be noted that r_{corr} is determined through this study, while b value was taken as the average time exponents from regression analyses, according to ISO 9224:2012 [2] and has a value of 0.523. The exponent b is a function of atmospheric factors (relative air humidity, temperature, duration of precipitation, content of sulfur dioxide in the air, chloride, PM particles, etc.). The recommendation of many authors is b=0.77 for the industrial environment [3].

The law that describes the change in the corrosion rate over time of the analyzed accelerated test methods from the previously given equation (1) is shown in Figure 1. The heuristic model, on which this study focuses is described, is based on the measurement of mass loss and consequently the corrosion rate, as a function of different atmospheric parameters: temperature, relative air humidity, TOW, as well as SO_2 content in the air. This means that the adopted model is quite simple to apply, although the application of each model refers exclusively to the atmospheric conditions for which the adopted parameters are valid, i.e., it is related to the observed locality.

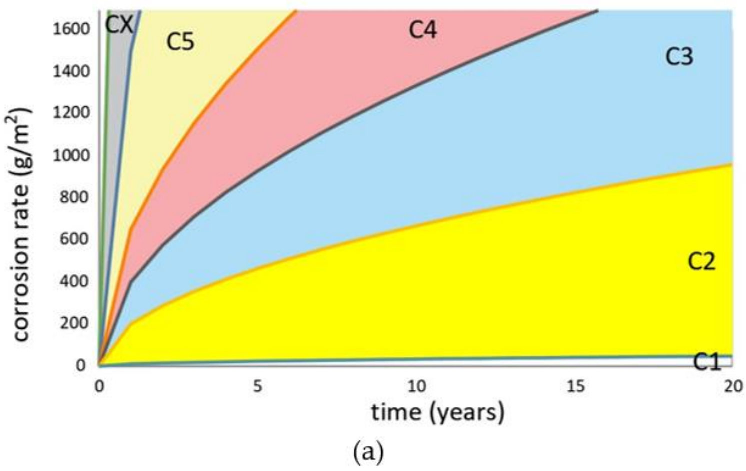

Figure 1. *Long-term corrosion rate prediction based on a linear model for corrosivity categories C1, C2, C3, C4, C5, CX according to ISO 9223*

It should be noted that the prediction for each corrosivity category in Figure 1 is made for within the ranges specified in ISO 9223:2012 [1]. In order to compare the responses of the construction subjected to different classes of corrosion in the linear region, the intervals for each category of corrosivity are shown separately.

2.3 Atmospheric Pollutants

The average monthly SO_2 concentration values for the automatic air quality monitoring station in City Park in Bor is shown in Table 2. The average of SO_2 values, measured for the period of experiment, are reported by the Annual Report on the air quality in the Republic of Serbia, Ministry of Environmental Protection, Environmental protection agency.

Table 2. *Mean monthly concentration of SO_2 (μg/M^3) and the maximum measured value during experiment duration [4]*

Month	Bor-City Park
the maximum measured value for the duration of the experiment	299,9 (measured on 01.05.2017)
mean value during the duration of the experiment	44,0

3. RESULTS AND DISCUSSION

3.1 Corrosivity Classification on the Basis of Calculated Corrosion Rate in the First Year

The average corrosion rate in the first year may be obtained as follows, expressed by the mass loss per unit area or reduction the specimen thickness:

$$r_{corr} = \frac{\Delta m}{At} \ [\mathrm{g/(m^2a)}] \qquad (2)$$

$$r_{corr}' = \frac{\Delta m}{AtD} [\mu\mathrm{m/a})] \qquad (3)$$

where t is a time of exposure in years (a), A is the initial total surface area of specimen (m^2), D is density (g/m^3), a Δm je the mass loss during the test (g).

The accelerated methods were used to determine the initial atmospheric corrosion of steel S235JR in the industrial environment at the site of Bor. The mass loss ratio increases continuously due to the increase in corrosion time or increase in corrosion factors. In accordance with ISO 9226:2012 [5], after determination the initial total surface area of specimen A mass loss during the test Δm, the average corrosion rate in the first year may be obtained from equations (2) and (3). The corrosion rate of the S235JR steel is shown in Table 3.

Table 3. *Corrosion rate and mass loss values of analyzed specimens*

Label of specimen	Mass loss (g)	Mass loss ratio ρ	r_{corr} (g/(m^2*a))	r_{corr}' (µm/a)
AF	7.28	0.0195	72.53	9.225

Table 4 shows the mean annual values of meteorological parameters and atmospheric pollutants. Based on these values and corrosion rate in the first year of exposure, the corrosivity category of external atmospheric corrosion stations is obtained.

Table 4. *Outdoor atmospheric corrosion stations near to the Sulphuric Acid Plant (AF) in Bor. The environmental characteristics and corrosivity.*

Atmosphere	Location	TOW (h/year)	SO_2 (mg/m^2)	Corrosion rate in the first year (µm)	ISO 9223 corrosivity category	Corrosivity level
Industrial	AF	2640	44,03	70,75	C3	high

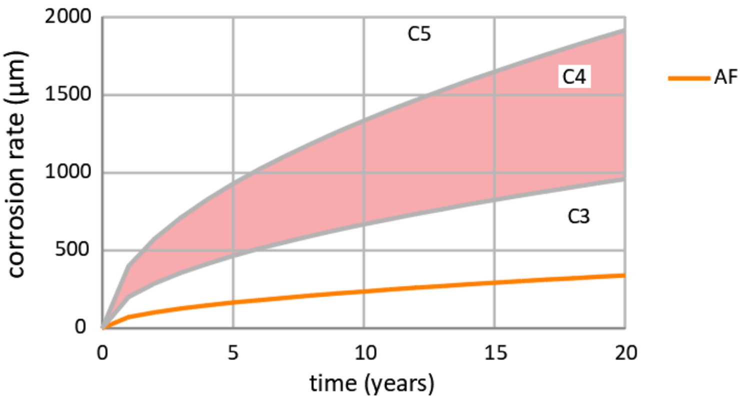

Figure 2. *Long-term prediction of corrosion rate on the power linear model for corrosivity categories C3 with exposure time at location AF (Sulphuric Acid Plant)*

4. CONCLUSION

The obtained results and data from this work should contribute to the understanding of the problem of strength capacity and durability of the steel structures weakened by corrosion in the industrial environments such as in Bor, where there are numerous inhibitors of the atmospheric corrosion.

A long-term prediction of corrosion rate, with the help of guantitative data from the accelerated corrosion testing for the industrial environments such as in Bor, could be given, as well. This could be very useful for everyday engineering practice.

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