

Electrochemical evaluation of the corrosion behaviour for structural steel SAE 1005 exposed to two different atmospheres (urban and industrial) and comparison with atmospheric corrosion gravimetric measurements

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Abstract. The Atmospheric corrosion is a phenomenon we see every day in our environment that arises due to environmental pollution we generate, there is currently very little information on atmospheric corrosion in the department of Boyacá and in general, in Colombia. The aim of this paper is to analyse which of these two environments is more aggressive and wherein the steel corrodes faster. To analyse these phenomenon specimens made in steel SAE 105 exposed for five months to the atmosphere in the municipalities of Tunja and Nobsa (an urban atmosphere and other industrial atmosphere) were installed, a control was carried to verify the amount of time that will be exposed each of these samples to the atmosphere, of Thus it may determine the lifetime of a structural steel. For the analysis of these samples electrochemical tests were carried out to calculate the rate of corrosion and resistance to polarization, also the gravimetric method be conducted to compare what was the amount of mass lost during the time of exposure to each of the samples.

1. Introduction

The atmospheric corrosion of steel passes through a mechanism of electrochemical nature. The electrolyte consists of an extremely thin film of moisture or an aqueous film, the metal appears noticeably when wet [1]. Electrolyte film under most exposed metals corrode in the atmosphere by means of cathodic oxygen reduction process. This phenomenon of corrosion is present everywhere causing considerable losses in terms of structures because of this electrochemical analysis being made so far have taken great importance due to the destruction of the materials [2,3].

This work aims at comparing two environments: one unpolluted (Tunja) and other industrial (Nobsa). SAE 1005 reference used in the structural steel industry was taken, and thus to determine their differences of atmospheric corrosion behaviour in these two municipalities, considering simultaneous and during the first five months of exposure posed a year's exposition, to study regarding the deterioration manifested by gravimetric measurements and compared to the respective electrochemical measurements in the laboratory.

2. Methodology

Steel is characterized by spectroscopy arc. Plates 10cm wide, 15cm long and 1mm thickness are subjected to a first pickling with hydrochloric acid. Immediately the plates are weighed on an analytical



balance, and installed in test stations in Tunja and Nobsa. After a month of exhibition, the first sample is taken and this is again weighed. The sample is taken to the laboratory where electrochemical tests will be done to find their corrosion rate and polarization resistance. Finally the sample is analysed and is subjected to a second pickling with Hexamethylene tetramine and finally is weighed again on an analytical balance. For the electrochemical test was used Na_2SO_4 electrolyte of 3.5%, a scan rate of 2mV/s, an exposed area of $0,95\text{cm}^2$ with a sweep from -250mV to +250mV with respect to Ecorr (Corrosion Potential).

2.1. Experimental design

The experimental matrix has two factors: sampling site, with two levels that are Tunja and Nobsa; and exposure time, which corresponds to the first five months of this study. The response variables arise from electrochemical tests and gravimetric method [4].

2.2. Experimental equipment

2.2.1 Analytical balance. This balance allows monitoring changes in mass with a definition of thousandths of a gram and is essential for gravimetric measurements by weight little difference formed oxide.

2.2.2. Electrochemical equipment. The Gamry G-750 Potentiostan-Galvanostats, an electrode Ag/AgCl and a flat electrochemical cell was used for generate the potentio-dynamics and LPR curves and is located in the Materials Lab of the Universidad Antonio Nariño, Tunja, Colombia.

2.3. Methods

The plates are located in two stations belonging to the University of Nariño in Tunja and Nobsa, assembled according to ASTM G50 standard [5].

2.3.2 Gravimetric. It is performed according to ASTM standard setting G1L cleaning for different chemicals for this etching an acid is used in a solution of 3.5g hexamethylene tetramine serving as inhibitor and 1000ml of distilled water. Additionally calculates the Pilling-Bedworth ratio that relates the volume of oxide formed with the volume of metal consumed [6].

2.3.2. Electrochemical. The response variables for electrochemical tests are back extracted from the Tafel approximation, in the case of potentio-dynamic curves and LPR test shows a value of the linear polarization resistance [7].

3. Results

Mass measurements exhibit the behaviour of oxidation of the samples at each station as a function of exposure time.

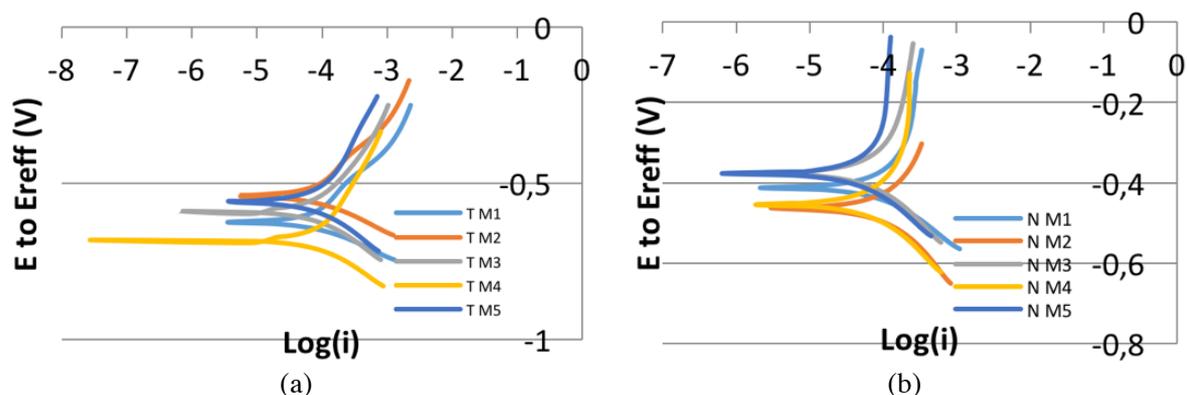


Figure 1. Curves Tafel for the months of exposition (a) Tunja and (b) Nobsa.

The data obtained are compared with Bedworth-Pilling factor that determines the behaviour of the mass loss of the substrate and the oxide layer generated (see Table 1).

The obtained results are reported in the Figure 1 and in the Table 2. In the potentiodynamic graphics (Figure 1), the x axis is the base 10 logarithm of current (Ampere) and the y axis is the Potential E in Volts.

Table 1. Resume of the gravimetric measurements.

| City and month | Initial weight (g) | Net weight after exposure (g) | Weight Without Rust (g) | Rust weight (g) | Weight loss of steel (g) | Percentage loss (%) | Exposure time (hours) | C.R. (mm/y) | Bedworth Pilling Ratio |
|----------------|--------------------|-------------------------------|-------------------------|-----------------|--------------------------|---------------------|-----------------------|-------------|------------------------|
| Nobsa 01 | 134,09 | 135,46 | 133,36 | 2,10 | -0,732 | 0,0055 | 720 | 0,0761197 | 4,2978038 |
| Nobsa 02 | 133,75 | 135,91 | 130,64 | 5,27 | -3,116 | 0,0233 | 1440 | 0,1620142 | 2,5336787 |
| Nobsa 03 | 134,71 | 135,17 | 130,63 | 4,54 | -4,078 | 0,0303 | 2160 | 0,1413552 | 1,6678116 |
| Nobsa 04 | 134,67 | 136,98 | 133,36 | 3,62 | -1,315 | 0,0098 | 2880 | 0,0341863 | 4,1240240 |
| Nobsa 05 | 134,48 | 135,18 | 130,63 | 4,55 | -3,845 | 0,0286 | 36000 | 0,0079967 | 1,7727742 |
| Tunja 01 | 132,1 | 132,07 | 131,97 | 0,10 | -0,120 | 0,0110 | 720 | 0,0124786 | 1,2484097 |
| Tunja 02 | 133,6 | 133,96 | 133,36 | 0,60 | -0,280 | 0,0021 | 1440 | 0,0145584 | 3,2101963 |
| Tunja 03 | 134,5 | 135,17 | 133,35 | 1,82 | -1,170 | 0,0087 | 2160 | 0,0405556 | 2,3303647 |
| Tunja 04 | 133,3 | 134,26 | 132,26 | 2,00 | -1,030 | 0,0077 | 2880 | 0,0267771 | 2,9089157 |
| Tunja 05 | 133 | 133,36 | 130,63 | 2,73 | -2,320 | 0,0174 | 36000 | 0,0048251 | 1,7628406 |

Table 2. Resume of the electrochemical variables response with the B-P ratio.

| Nobsa (Industrial Atmosphere) | | | | | |
|-------------------------------|--------------------|--------------------|---------------------|-----------|-------------|
| Coupon | β_a (mV/dec) | β_c (mV/dec) | CR 10^{-3} (mm/y) | LPR (Ohm) | B. P. ratio |
| N1 | 391,9 | -180,9 | 1,34 | 108,7 | 4,2978 |
| N2 | 351,9 | -228,8 | 1,38 | 286,6 | 2,5336 |
| N3 | 318,2 | -178,5 | 0,71 | 410,08 | 1,6678 |
| N4 | 362,7 | -160,5 | 0,91 | 375,3 | 4,1240 |
| N5 | 295,1 | -120 | 0,48 | 503,3 | 1,7727 |
| Tunja (Urban Atmosphere) | | | | | |
| Coupon | β_a (mV/dec) | β_c (mV/dec) | CR 10^{-3} (mm/y) | LPR (Ohm) | B. P. ratio |
| T1 | 260,1 | -97,2 | 0,42 | 148,8 | 1,2484 |
| T2 | 191,1 | -93,6 | 0,34 | 143,7 | 3,2102 |
| T3 | 268,8 | -155,8 | 0,99 | 250,4 | 2,3303 |
| T4 | 281,9 | -124,6 | 0,84 | 245,9 | 2,9089 |
| T5 | 351 | -153,6 | 0,59 | 273,5 | 1,7628 |

4. Discussion

The gravimetric method yields real values of the loss of material. It is shown in Figure 2 that the attack Nobsa is much more aggressive than in Tunja for any month.

In Figure 3 it shows that the corrosion rates are very similar, unlike what happens with the gravimetric method. This may be due to oxide layers which are applied potentiodynamic curves have in common

the same Na₂SO₄ electrolyte at the same concentration. However we note that the attack Nobsa is more pronounced, especially in the first two months.

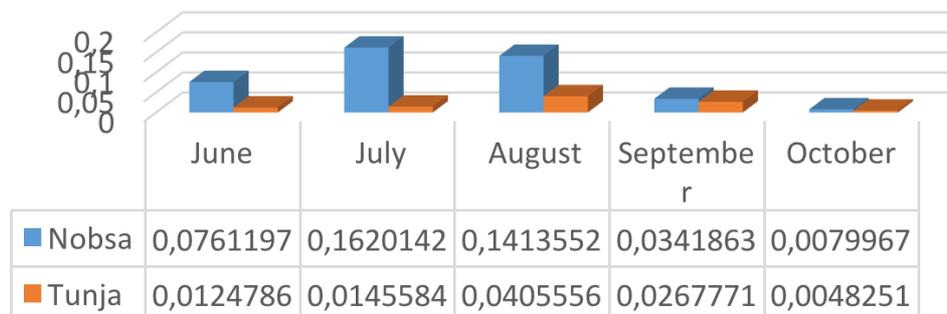


Figure 2. Corrosion Rate Gravimetric Method (mm/y) comparison for the two stations in function of exposition time.

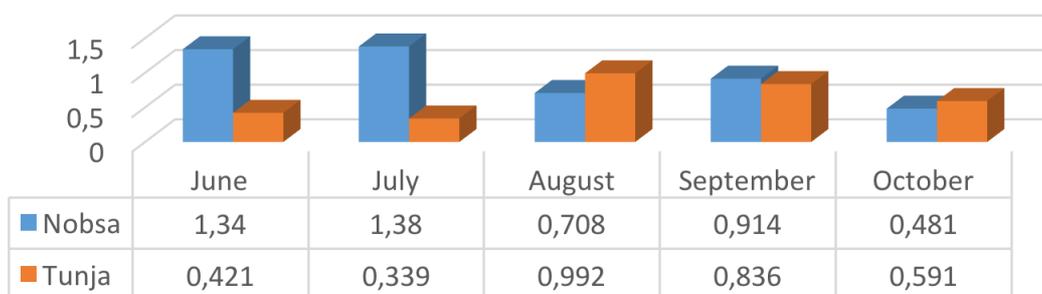


Figure 3. Corrosion Rate Electrochemical Method (mm/y) comparison for The two stations in function of exposition time.

5. Conclusions

As noted in the study of air quality for Sugamuxi [8] this industrial environment is high presence of SO₂ unlike urban environments such as the city of Tunja. Faster attack Nobsa (about the first and second month) compared to Tunja (3 and 4 months) was observed.

The oxide layer presents a series of etched ment that is related to rainfall. The rain acts as a cleaning mechanism of the plates. This was evident when calculating the Pilling-Bedworth ratio for each month and a more pronounced effect was noted in Nobsa.

The corrosion rates are not as high after the third month due to the amount of oxide that accumulated on the surface layer causes which serve as protective preventing more contaminants from seeping inside the steel on forming.

References

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