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## Corrosion Rate of Low Carbon Steel for Construction Materials in Various *NaCl* Concentrations

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# Corrosion Rate of Low Carbon Steel for Construction Materials in Various *NaCl* Concentrations

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**Abstract.** Corrosion rate data of metal materials for construction; particularly carbon steel used in wet environments containing *NaCl*, is very important due to safety reasons. It is, therefore, necessary to investigate the corrosion rate of construction steel in various *NaCl* concentrations. The objective of this work is to study the corrosion rate of low carbon steel by varying the concentration of *NaCl* in distilled water, using a loss of weight method. To carry out this research, 25 low carbon steel samples, of 80x24x3 mm sized coupons, were made. Samples were divided into 7 treatment groups, and weight loss measurements were carried out for 240, 480, 720, 960, 1200, 1440 and 1750 hours, respectively. Experimental data was obtained by totally exposing the samples to *NaCl* solutions of 2%, 3%, 4% and 5%, and one treatment in distilled water only. The results show that *NaCl* concentration significantly influenced the corrosion rate for all solution variations. The most obvious effect was observed in the first 240 hours of exposure time for all concentrations of *NaCl*; which then gradually decreased until an exposure time of 1750 hours was reached. The average corrosion rate value was 0.2427  $\mu\text{m}/\text{year}$ .

## 1. Introduction

Carbon steel is widely used in engineering applications for equipment or construction materials and accounts for approximately 85% of Worldwide annual steel production [1,2]. It is also used for a variety of everyday life applications, such as reinforcing concrete, underground pipes, bridge construction, the petroleum industry and others [3]. The application of steel for various purposes is always related to the environment, such as air, water and soil. Each of these environments has different corrosively levels depending on ion concentration, temperature, relative humidity, and solution resistance. For example, the *NaCl* content is different in solution [4].

Several studies have been conducted to determine the corrosion rate of steel in *NaCl* [5], in soil and in open air or atmosphere environments [6]. Research on the corrosion rate of steel in *NaCl* shows that the concentration of *NaCl* in water significantly increases the corrosion rate [7]. Similarly, the corrosion rate of steel in soil show that the resistance and concentration of ions are influencing factors. The corrosion rate of steel in each electrolyte media can be identified by measuring the corrosion potential and current density that occurs during media interaction. In addition, the corrosion rate can be determined by measuring weight loss during exposure to the corrosive media [8].



Generally, only studies on the corrosion rate of steel in single  $NaCl$  solutions and significant results have been reported. Several of the studies on corrosion rates by the authors only used one type of solution that contained  $NaCl$ . However, only a few studies on corrosion rates affected by variation  $NaCl$  in solutions, are found within the literature. Therefore, a study on the effect of  $NaCl$  concentration in distilled water needs to be clearly verified, for reliability reasons, for construction materials and enrichment of the welding field reference.

The objective of this work is to study the effect, of various concentrations of  $NaCl$  solution in distilled water with air supply, on corrosion rate using a weight loss method.

## 2. Material and Method

### 2.1. Material

The material used in this study is construction steel in the form of a 3-mm thick plate. The material was purchased from a construction store located in the Banda Aceh area. The steel is identified as a low carbon steel; but requires verification through composition testing to ensure the material's element contents. The test object used in this study is a plate of carbon steel, with a size of 80x24x3 mm. The form and size of the specimen used is shown in Figure 1.

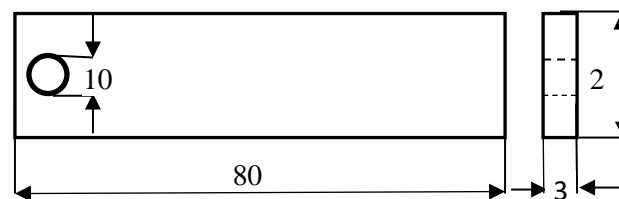


Figure 1. Shape and size of specimen (mm)

### 2.2. Experimental methods

The number of samples used is 25 pieces, divided into 5 groups of treatment, namely: (1) 5 samples were exposed to 2%  $NaCl$ ; (2) 5 samples in 3%  $NaCl$ , (3) 5 samples in 4%  $NaCl$ , (4) 5 in 5%  $NaCl$  and (5) 5 in distilled water. During immersion, the solution was supplied with air. The effects of different immersion times and  $NaCl$  concentrations on the corrosion rate of low carbon steel substrates were investigated. The samples were exposed to different corrosive environments and left for a stipulated period of 75 days, with a 240 hours interval of collection, weighing and re-immersing into the various environments. The data was collected 5 (five) times for each observation group. Table 1 shows the distribution of samples for each treatment.

Table 1. The distribution of samples for each treatment

Treatment (% $NaCl$ )	Exposure time (hours)						
	240	480	720	960	1200	1440	1750
0	5	5*	5*	5*	5*	5*	5*
2	5	5*	5*	5*	5*	5*	5*
3	5	5*	5*	5*	5*	5*	5*
4	5	5*	5*	5*	5*	5*	5*
5	5	5*	5*	5*	5*	5*	5*

\*The same sample as in a 240-hour column, re-immersing for other exposure times.

The samples were divided and abstracted sequentially using silicon carbide abrasive paper with grit from 180 to 600. The specimens were then washed, cleaned with ethyl alcohol and dried before initial weighing (to a precision of 3 decimal places) before the immersion test to assess weight loss. The

samples were immersed in different concentrations of *NaCl* solution. Corroding media preparation was performed with reference to the work by [9].

After surface preparation, the dimensions of the samples were carefully measured to allow the calculation of the surface area. Corrosion rates were calculated using the following Eq. 1 [10].

$$\text{Corrosion Rate (CR, mm/year)} = \frac{87,6 \times W_f}{A \times t \times \rho} \quad (1)$$

where; *W* is the weight loss (mg), *A* is the surface area (cm<sup>2</sup>), *ρ* is the density (g/cm<sup>3</sup>) and *t* is the exposure time (hr). The original area was used to calculate the corrosion rate throughout the test using Eq. 2:

$$A = 2 \times [(L \times B) + (B \times T) + (L \times T)] \quad (2)$$

where; *L* is the length, *B* is the width and *T* is the thickness of the samples. After measuring, the specimens were degreased by washing in tap water, rinsed with ethanol, and then dried and weighed. Every 240 hours of interval testing period, the samples were taken out of the *NaCl* solution, washed in tap water, and distilled water, and then rinsed with ethanol. The samples were then weighed for the weight loss calculation. The washing, drying and weighing process, to determine weight loss and data recording, was repeated consistently. Weight loss was calculated using Eq. 3 as follows;

$$W_f = W_0 - W_t \quad (3)$$

where *W*<sub>0</sub> is the original weight and *W*<sub>*t*</sub> is the weight by *t* hour.

The weight loss method was used to obtain the corrosion rate of low carbon steel immersed in *NaCl* solution. The equipment and materials needed to perform this research were as follows; *NaCl* salt, digital scales, plastic brush, glass container, acetone, beaker, magnetic stirrer, distilled water, abrasive paper with grits of 600 to 1000, and a Metallurgical microscope.

This study applied a quantitative analysis method to obtain the corrosion rates based on the weight loss method employed. This was performed by totally immersing the coupon samples in several different concentrations of *NaCl* solution, namely 2%, 3%, 4%, and 5% *NaCl* and in distilled water. Measurement of weight loss of steel was as a function of time and % *NaCl* in water. Weight loss measurement of steel during exposure and after washing was carried out according to ASTM G31-72 standard [11].

### 3. Results and Discussion

#### 3.1. Material Characterization

Material characterization is intended to determine the type of material used in the study. This is because the material used was purchased from a metal material store. The characterization required includes tensile strength, hardness, toughness, micro-structure and chemical composition. Tensile strength is in the form of a stress-strain relationship (as shown in Figure 2). Material tensile strength data for the sample is shown in Table 2.

Table 2 shows an average yield strength of 356 MPa, a maximum tensile strength of 496 MPa, an average modulus of elasticity (Young's Modulus) of 19 GPa and an average tensile strain of 32%. Meanwhile, the average hardness value obtained was 140 HV.

Table 2 Tensile properties of low carbon steel

Yield Strength (MPa)	Tensile Strength (MPa)	Strain (%)	Young Modulus (GPa)
356	496	32	19

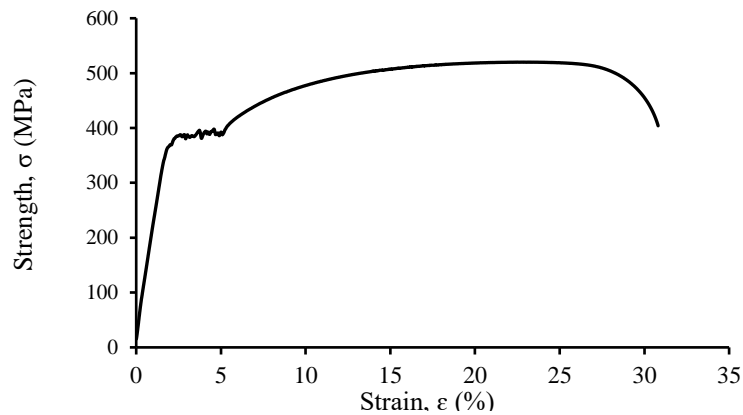


Figure 2 Low carbon steel stress-strain relationship

As mentioned previously, the material used in this research was of a low carbon steel type construction. This can be proven from the results of its chemical composition. The average percentage of carbon contents was 0.231%; thus, identifying that the mild steel contained a maximum of 3% C; or also known as low carbon steel. Furthermore, the results of the microstructure observations also show that the research material was low carbon steel. The microstructure was dominated by bright coloured phases as ferrite and several dark coloured phases of perlite. Figure 3 shows that the microstructure of the research material is verified as low carbon steel.

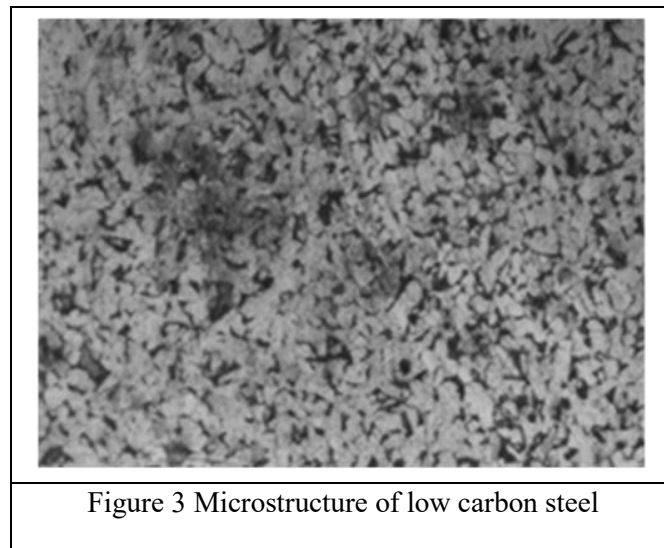


Figure 3 Microstructure of low carbon steel

### 3.2. Corrosion rate

Corrosion rate is the degradation rate of a material exposed in a surrounding environment, both aqueous and atmospheric. Material degradation is directly proportional to material weight loss and inversely proportional to surface area, density and exposure time (as stated in Eq. 1). Figure 4 shows corrosion rate versus exposure time for various *NaCl* (% *NaCl*) concentrations.

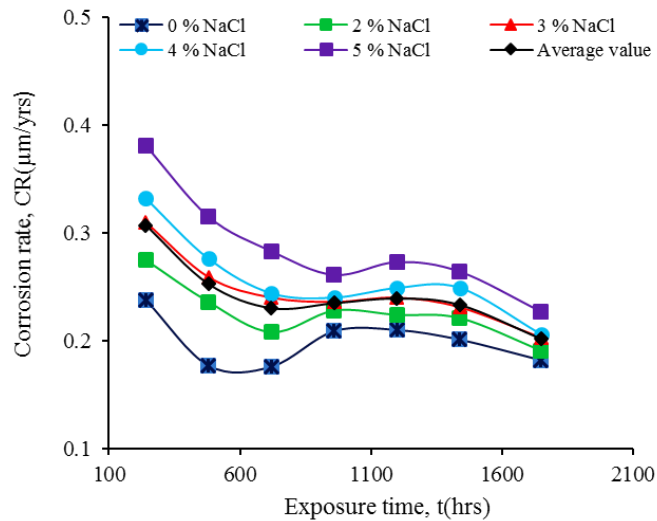


Figure 4 Corrosion rate vs. exposure time for various NaCl concentrations

The corrosion rate of the sample in distilled water was lower than samples exposure in 2, 3, 4 and 5 % *NaCl*. This was consistent with several results of previous studies [9,12]. An increasing concentration of *NaCl* in the solution increased the corrosion rate of the samples. The corrosion rate during the first 10 days was high; but decreased when the exposure time reached 40 days. It was then stable up to 60 days of exposure time and decreased again after 60 days. The corrosion rate decreased generally and the average value was in the range 0.247  $\mu\text{m}/\text{year}$ . Interestingly, the average value of corrosion rate showed a decrease below 40 days of exposure time, then stable up to 60 days and down until 75 days of immersion was reached. The decrease in corrosion rate value was due to increased exposure time, while weight loss remained stable. Therefore, the corrosion rate chart tends to be linearly negative.

#### 4. Conclusion

Corrosion rate is significantly influenced by different *NaCl* concentrations in a solution. Corrosion rate during the first 10 days was high, but gradually decreased when the exposure time reached 40 days of exposure. It was then stable up to 60 days of exposure and decrease again after 60 days. The corrosion rate generally decreased and the average value was in the range 0.247  $\mu\text{m}/\text{year}$ .

#### 5. Acknowledgement

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